PDP-11

Software Handbook

digital

PDP-11

Software Handbook

digital

Unless otherwise noted, K = 1,024, M = $1,024^2$.

PREFACE

This Handbook is intended for a spectrum of customers with varying expertise; so, if you are reading about computer software for the first time or if you are an expert, you will be able to learn something new, and to make better informed decisions about Digital's operating systems and associated software.

It's not necessary to read straight through this Handbook to learn what you want to know about PDP-11 software. Whether you're interested in the higher-level programming languages, the user-level utilities, the data managers, networks, or the operating systems themselves, you'll find a concise description and an explanation of the benefits to be derived from each software product. The book is arranged in small groups of chapters. The Table of Contents gives details of the chapters and should help you find material of interest. If you are reading about computers for the first time, for example, you will probably want to read Chapters 1 and 2 before attempting to study the more user-oriented matter in latter parts of the Handbook. Operators and users may want to go directly to the chapters that describe programming languages, operating systems, file management, database management, and distributed processing and networks.

The goal of this Handbook is to introduce PDP-11 system software without delving into the degree of technicality you'll find in the user documentation delivered with your system. A glossary of software terms, an alphabetic listing of most commonly used abbreviations, and a thorough index are included for your convenience. There are also appendices on DECUS (the Digital Equipment Computer Users Society), and *The PDP-11 Software Sourcebook*. DECUS helps its membership obtain specialized software developed by other members. *The PDP-11 Software Sourcebook* describes over 1200 applications available for PDP-11 users.

Digital is constantly improving existing products and introducing new ones. Your best source for the latest word on software is your sales representative, who can keep you up to date on recent releases and enhancements to traditional products.

Contents

4 RSTS/E

5 RT-11

6 DIGITAL STANDARD MUMPS

7 MICROPOWER/PASCAL

8 V7M-11

9 INTERACTIVE APPLICATION SYSTEM (IAS)

10 PROGRAMMING LANGUAGES

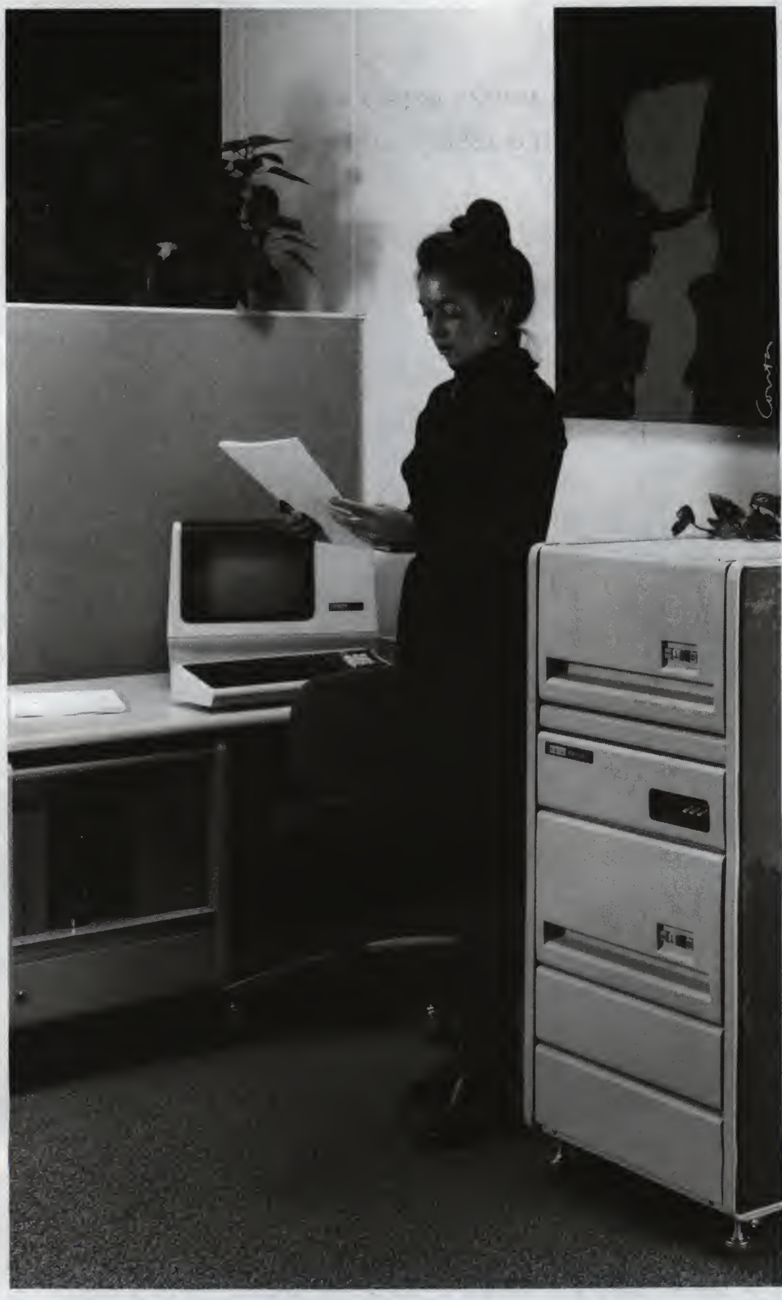
11 PDP-11 MACRO

12 FORTRAN

13 THE BASIC LANGUAGE

14 COBOL

APPENDICES



Chapter 1

Introduction to PDP-11 Software

Compatibility is the Key to the PDP-11 Family.

The PDP-11 computer family is a wide range of compatible processors complemented by a variety of peripheral devices, software, and services.

This Handbook discusses the major software available for the PDP-11 family of computers, and explains its features and benefits. *Software* is the collection of programs or routines that allow people to use computer hardware. Generally speaking, *programming* creates and changes software, while engineering design alters hardware.

Because your computer hardware is only as useful as the software operating with it, you should understand certain software concepts. This chapter and the next introduce some basic software concepts, at the same time briefly showing how Digital implements those ideas.

Compatibility is a key feature of both hardware and software in the PDP-11 world. Small systems can grow easily into larger ones as your data processing needs increase, without the heavy reinvestment required in starting from scratch. Your software can run in different PDP-11 hardware environments. For example, most operating systems can run on several processors, and all can grow to accommodate new languages, peripherals, and other improvements.

While a few of the characteristics of software may vary from application to application, compatibility helps guarantee that personnel and programs can move among systems with a minimum of trouble.

The FORTRAN-77 programming language, for example, runs on several operating systems. If you've learned FORTRAN-77 on one system, you could, with little difficulty, write programs on another PDP-11 system running a different PDP-11 operating system. Likewise, a FORTRAN-77 application program can be readily transported to any Digital PDP-11 system that supports the language.

Most software can also migrate with little difficulty across system families— from the Professional series of personal computers— to PDP-11s— to VAX.

The flexibility of PDP-11 hardware/software systems allows you to select the most appropriate hardware, operating system, and languages to meet your immediate needs, while ensuring your system can grow whenever you need it to.

Powerful Communications Networks Link PDP-11s.

Digital produces powerful software and hardware that permit the linking of computers and terminals into flexible configurations called *networks*. Networks can vastly increase the efficiency and cost-effectiveness of data processing operations. No matter where your terminals or processors are located, they can be connected in ways that allow the exchange of information, files, programs, and control, as well as the sharing of peripherals. Small computers can access the powerful capabilities of mainframes when they are networked, while large computers can take advantage of smaller dedicated systems which have been chosen for specific application environments.

Chapter 22 outlines the entire spectrum of PDP-11 networking and distributed processing capabilities.

Digital Offers a Wide Variety of Operating Systems for the PDP-11 Family.

An operating system not only provides access to the features of a processor, it also organizes a processor and peripherals into a useful tool for a certain range of applications. Some systems can manage only one user's task at a time. Others accept many tasks. Some systems support realtime applications, that is, applications in which the computer is required to respond within given time limits to an external message, to make a decision, and to respond quickly (for example, flight simulator control, power plant management, and laboratory experiment supervision). Still others support timesharing applications, in which the central processor is allocated according to a scheme of priorities, privileges, and time quotas (for example, airlines reservations systems and automated teller machines).

The operating systems featured in this Handbook are:

MICRO/RSX	Packaging based on the multiuser, multitasking, RSX-11M-PLUS operating system and designed especially for the MICRO/PDP-11.
RSX-11M-PLUS	Realtime System Executive Operating System-PLUS for high-end PDP-11 Processors A large realtime system meant to take advantage of enhanced hardware features and larger memory available on the PDP-11/44 and PDP-11/70 processors. RSX-11M-PLUS is a superset of RSX-11M.
RSX-11M	Realtime System Executive Operating System for PDP-11 Processors A small to moderate sized realtime multiprogramming system that can be generated for a wide range of application environments—from small, dedicated systems to large, multipurpose realtime application and program development systems.
RSX-11S	Realtime System Executive Operating System for PDP-11 Processors

	A small, execute-only member of the RSX-11 family for dedicated realtime multiprogramming applications (requires a host RSX-11M, RSX-11M-PLUS, IAS, or VAX/VMS system).
RSTS/E	Resource-Sharing Timesharing System/Extended Operating System for PDP-11 Processors A moderate to large-sized timesharing system, expressly designed to optimize the interplay between people and system; RSTS/E is used in a variety of multiuser applications ranging from business data processing to academic instruction.
RT-11	Realtime Operating System for PDP-11 Processors A small, single-user foreground/background system that can support a realtime application job's execution in the foreground and an interactive or batch program development job in the background.
CTS-300	Designed to support small business applications, CTS-300 is based on RT-11 and uses DIBOL (Digital's Business-Oriented Language), system utilities, and program development tools.
DSM-11	Digital-Standard MUMPS Operating System for PDP-11 Processors A small to large-sized timesharing system that offers a unique fast-access data storage and retrieval system for large database processing; originally designed for medical record management and now available for similar database applications.
MicroPower/Pascal	An advanced software toolkit that describes two system environments for developing microcomputer applications: a host system that you use to create, build, and test realtime application software, and a target minicomputer system that runs the software.
V7M-11	A simple, elegant, easy-to-use interactive programming environment for multiple users based on Bell Laboratories' UNIX* operating system Version 7. (*UNIX is a registered trademark of Bell Laboratories)
IAS	Interactive Application System for PDP-11 Processors This traditional product is a large, multiuser timesharing system that allows real-time application execution concurrently with time-shared interactive and batched processing.

Chapter 2 of this Handbook defines and illustrates the concept of an operating system.

PDP-11 Operating Systems Support Packaged Together and Sold Separately Software Products.

Some software products are packaged with other products and sold together as a unit. The RSTS/E operating system includes a BASIC-PLUS language processor; MUMPS-11 language is inseparable from the DSM operating system. Similarly, one form or another of the Record Management Services (RMS) is included in each operating system that supports them.

Separately sold products, on the other hand, are distinct options, not necessarily included as part of any other software. Special application software packages such as stress analysis, statistical analysis, or general accounting that you might use in your application are sold separately from the operating systems they work with.

The flexibility produced by this approach aids in tailoring a system to your specific needs, without sacrificing or omitting vital routines and utilities.

Digital's operating systems support a considerable variety of software products, both those that are packaged together and those that are sold separately, along with supporting numerous central processors and peripherals. The three tables that follow compare the processors on which PDP-11 operating systems run, the languages supported under each system, and the configurations of typical systems.

Since both hardware and software are continually evolving and being improved, these tables are meant to be used as guides to what is currently available.

Table 1-1 Processors

Operating Systems	Processors									
	PDP-11 Family									
	MICRO/ PDP-11	LSI-11/2 BASED	11/03L	11/23	11/23- PLUS	11/04	11/24	11/34	11/44	11/70
MICRO/RSX	X									
RSX-11M-PLUS	X				X		X		X	X
RSX-11M	X			X	X	X	X	X	X	X
RSX-11S	X	X	X	X	X	X	X	X	X	X
RSTS/E	X				X		X	X	X	X
MICRO/RSTS	X									
V7M-11	X			X	X		X	X	X	X
RT-11	X	X	X	X	X	X	X	X	X	
DSM-11	X			X	X		X	X	X	X
IAS								X	X	X

Table 1-2 Languages

Languages	Operating Systems							
	PDP-11 Family							
	RT-11	DSM-11	RSTS/E	RSX-11M-PLUS	RSX-11M	RSX-11S	V7M-11	IAS
MACRO	X		X	X	X	X^1		X
MU BASIC	X							
BASIC-II	X		X^2	X	X			X
BASIC-PLUS			X					
BASIC-PLUS-2			X	X	X		X	X
COBOL-81			X	X	X			
DIBOL-83	X^2		X	X				
FORTRAN-77			X	X	X	X^1	X	X
FORTRAN-IV	X		X	X	X	X^1		X
PASCAL				X	X			
Standard MUMPS		X						
CORAL 66				X	X	X		X
MICROPOWER/PASCAL	X							
C							X	

X^1 Task Execution only.
X^2 Bundled as CTS-300.

Table 1-3 Typical System

TOPIC	RSX-11M-PLUS
SYSTEM TYPE:	Moderate sized real-time multiprogramming system that is optimized for large multipurpose real-time applications and program development systems
CPU:	PDP-11/23-PLUS, 11/24, 11/44, 11/70 MICRO/PDP-11 with MICRO/RSX
TYPICAL SYSTEM DEVICES:	RL02 Cartridge disk drive RK07 Cartridge disk drive RM02 Disk drive RM03 Disk drive RM05 Disk drive RP06 Disk drive
TYPICAL LOAD DEVICES:	RL02 Cartridge disk drive RK07 Cartridge disk drive TE16 Magtape TU77 Magtape TS11 Magtape
MINIMUM MEMORY (bytes):	256K
MAXIMUM MEMORY SUPPORTED (bytes):	3840K
HIGH-LEVEL LANGUAGES:	BASIC (opt.) BASIC-PLUS-2 (opt.) FORTRAN IV (opt.) FORTRAN-77 (opt.) PDP-11 COBOL (opt.) COBOL-81 (opt.)
COMMUNICATION CAPABILITIES:	DECnet-11M-PLUS (opt.) RSX-11 PSI/FR (opt.) RSX-11M/3271 PE (opt.) RSX-11 2780/3780 Emulator (opt.) RSX-11M-PLUS RJE/HASP (opt.)

Table 1-3 (cont.), Typical System

TOPIC	RSX-11M
SYSTEM TYPE:	Compact, efficient real-time multiprogramming applications and development system
CPU:	Any UNIBUS PDP-11 Processor and PDP-11/23, or PDP-11/70
TYPICAL SYSTEM DEVICES:	RK07 Cartridge disk drive RL02 Cartridge disk drive RP06 Disk pack drive RM02 Disk pack drive RM03 Disk pack drive
TYPICAL LOAD DEVICES:	RL01 Cartridge disk drive RL02 Cartridge disk drive RK07 Cartridge disk drive TE16 Magtape TS11 Magtape
MINIMUM MEMORY (bytes):	32K without concurrent program development 48K with concurrent program development and application execution
MAXIMUM MEMORY SUPPORTED (bytes):	56K (without memory management) 3840K (with memory management)
HIGH-LEVEL LANGUAGES:	FORTRAN IV (opt.) FORTRAN-77 (opt.) PDP-11 COBOL (opt.) COBOL-81 (opt.) BASIC (opt.) BASIC-PLUS-2 (opt.) CORAL-66 (opt.) PEARL-11 (opt.)
COMMUNICATION CAPABILITIES:	DECnet-11M (opt.) RSX-11 2780/3780 Emulator (opt.) RSX-11M/3271 PE (opt.) RJE/HASP (opt.) UN1004/RSX (opt.) MUX200/RSX-IAS (opt.) RSX-11M/SNA PE (opt.) RSX-11 PSI/FR (opt.) RSX-11 PSI/CAN (opt.) RSX DLX-11 (opt.) DX/11M (opt.)

Table 1-3 (cont.), Typical System

TOPIC	RSX-11S
SYSTEM TYPE:	Execute-only real-time multiprogramming applications system; requires RSX-11M, RSX-11M-PLUS, or VAX/VMS system for generation and program development
CPU:	All PDP-11 processors (LSI-11 based to PDP-11/70)
TYPICAL SYSTEM DEVICES:	None required
TYPICAL LOAD DEVICES:	TE16 Magtape TS11 Magtape
MINIMUM MEMORY (bytes):	16K 32K for on-line task loading or execution of tasks written in FORTRAN
MAXIMUM MEMORY SUPPORTED (bytes):	56K (without memory management) 3840K (with memory management)
HIGH-LEVEL LANGUAGES:	No compilers supported, but tasks are developed on host system using FORTRAN IV, FORTRAN-77, or CORAL 66
COMMUNICATION CAPABILITIES:	DECnet-11S (opt.) RSX DLX-11 (opt.)

Table 1-3 (cont.), Typical System

TOPIC	RSTS/E
SYSTEM TYPE:	General timesharing; up to 63 simultaneous users, which includes interactive terminal users, detached jobs and batch processing. MICRO/PDP-11 with MICRO-RSTS
CPU:	PDP-11/24 through PDP-11/70 with memory management and EIS
TYPICAL SYSTEM DEVICES:	RL02 Cartridge disk drive RK07 Cartridge disk drive RP06 Disk pack drive RM02 Disk pack drive RM03 Disk pack drive RM05 Disk pack drive RA60, RA80
TYPICAL LOAD DEVICES:	TE16 Magtape TU77 Magtape RL02 Cartridge disk drive RK07 Cartridge disk drive TS11 Magtape & Controller
MINIMUM MEMORY (bytes):	128K (without RMS) 248K (with RMS)
MAXIMUM MEMORY SUPPORTED (bytes):	248K (except PDP-11/44 and PDP-11/70) 1024K (PDP-11/24 and PDP-11/44) 3840K (PDP-11/70)
HIGH-LEVEL LANGUAGES:	BASIC-PLUS (inc.) FORTRAN IV (opt.) FORTRAN-77 (opt.) PDP-11 COBOL (opt.) COBOL-81 (opt.) BASIC-PLUS-2 (opt.)
COMMUNICATION CAPABILITIES:	RSTS/E-2780 (opt.) RSTS/E High Performance 2780/3780 Emulator (opt.) DECnet/E (opt.) RSTS/E 3271 PE (opt.) DX/RSTS (opt.)

Table 1-3 (cont.), Typical System

TOPIC	DSM-11
SYSTEM TYPE:	Data management timesharing facilities for up to 63 simultaneous users which includes interactive users and detached jobs
CPU:	MICRO/PDP-11 PDP-11/23/24/44 PDP-11/70
TYPICAL SYSTEM DEVICES:	RL02 Cartridge disk drive RM02 Disk pack drive RM03 Disk pack drive RM05 Disk pack drive RP06 Disk pack drive RA60, RA80, RA81
TYPICAL LOAD DEVICES:	RL01 Cartridge disk drive RL02 Cartridge disk drive RK07 Cartridge disk drive TS11 Magtape TE16 Magtape TU80 Magtape
MINIMUM MEMORY (bytes):	96K
MAXIMUM MEMORY SUPPORTED (bytes):	4Mb
HIGH-LEVEL LANGUAGES:	ANSI STANDARD MUMPS
COMMUNICATION CAPABILITIES:	DMC11 (opt.) DMR11 (opt.)

Table 1-3 (cont.), Typical System

TOPIC	IAS
SYSTEM TYPE:	Large, multiuser timesharing system; supports concurrent interactive, batch and real-time applications
CPU:	PDP-11/34 through PDP-11/70 with memory management
TYPICAL SYSTEM DEVICES:	RL01 Cartridge disk drive RK07 Cartridge disk drive RP06 Disk drive RM03 Disk drive RM05 Disk drive
TYPICAL LOAD DEVICES:	TE16 Magtape RL01 Cartridge disk drive RL02 Cartridge disk drive
MINIMUM MEMORY (bytes):	96K
MAXIMUM MEMORY SUPPORTED (bytes):	248K (PDP-11/34) or 3840K (PDP-11/44/70)
HIGH-LEVEL LANGUAGES:	FORTRAN IV (opt.) FORTRAN-77 (opt.) PDP-11-COBOL (opt.) BASIC (opt.) BASIC-PLUS-2 (opt.) CORAL-66 (opt.)
COMMUNICATION CAPABILITIES:	DECnet-IAS (opt.) IAS/2780 (opt.) RSX-11M/IAS RJE-HASP (opt.) MUX200/RSX-IAS (opt.)

Table 1-3 (cont.), Typical System

TOPIC	RT-11
SYSTEM TYPE:	Single user, real-time application Foreground/Background program development or batch job
CPU:	All PDP-11 processors (LSI-11 based products through the PDP-11/44) except the PDP-11/70 or VAX Family
TYPICAL SYSTEM DEVICES:	RL01 Cartridge disk drive RL02 Cartridge disk drive RK07 Cartridge disk drive RX01 Floppy disk drive RX02 Floppy disk drive
TYPICAL LOAD DEVICES:	RL01 Cartridge disk drive RL02 Cartridge disk drive RX01 Floppy disk drive RX02 Floppy disk drive TE16 Magtape TU58 Cartridge tape
MINIMUM MEMORY (bytes):	24K Single job 32K Single job with BATCH or MACRO 32K Foreground/Background
MAXIMUM MEMORY SUPPORTED (bytes):	60K for systems running the SJ or FB monitor 248K for systems running under the XM monitor
HIGH-LEVEL LANGUAGES:	BASIC (opt.) Multiuser BASIC (opt.) FORTRAN IV (opt.)
COMMUNICATION CAPABILITIES:	DECnet/RT (opt.) RT-11/2780/3780 PE (opt.)

Table 1-3 (cont.), Typical System

TOPIC	V7M-11
SYSTEM TYPE:	General purpose, multi-user, interactive operating system derived from the UNIX™ Timesharing System Version 7
CPU:	Any MICRO/PDP-11 or 11/23 through 11/70 with a line clock
TYPICAL SYSTEM DEVICES:	RL01/2 Cartridge disk drives RK06/7 Disk drives RM02 Disk drive
TYPICAL LOAD DEVICES:	TM11-TS03 Tape drive TM11-TU10 Tape drive TM02/3-TU77 Tape drives TM02/3-TU/TE16 Tape drives
MINIMUM MEMORY (bytes):	192K 256K recommended
MAXIMUM MEMORY SUPPORTED (bytes):	3.75M
HIGH-LEVEL LANGUAGES:	C FORTRAN-77 BASIC
COMMUNICATION CAPABILITIES:	UUCP UNIX to UNIX Communications Protocol MAIL WRITE

Chapter 2
Operating Systems

Operating Systems Manage Computer Needs.

An operating system is a collection of control programs and routines designed to make computer hardware devices easy to use. Operating systems vary greatly in the kinds of hardware with which they work, in the range of complexity of tasks they handle, in the degree of adaptability to special user purposes, and in the programming languages which they support.

Operating systems not only provide a way by which a user's specific program can run on the computer; they can also have a set of utilities and routines that manage such resources as printers and terminals, that detect errors in programs, that keep user accounts, that protect information, that warn the operator of failures—and much more.

Operating Systems Organize Work for You.

Operating systems are collections of programs that organize a set of hardware devices into a working unit that people can use. Figure 2-1 illustrates the relationship between users, operating system, and hardware.

PDP-11 operating systems consist of two sets of software: the executive (or monitor) software and the system utilities.

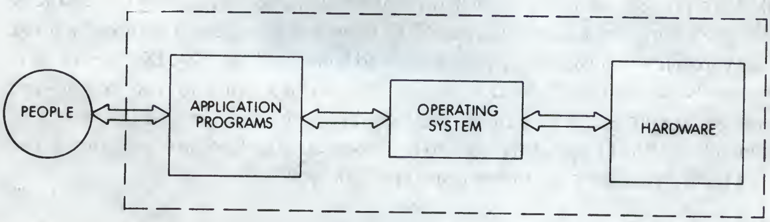


Figure 2-1 Computer System

An integrated set of routines, the *executive* acts as the primary interface between the hardware and a program running on the system, and between the hardware and the people who use the system. The executive's basic functions can be divided among the following services:

- User interface
- Programmed processing services
- Device and data management
- Memory allocation
- Processor time allocation

In general, an executive can have two distinct operating components: a memory-resident portion and a temporarily resident (called transient) portion. Typically, the operating system is delivered on a hardware medium, called the system device, such as a disk or magnetic tape. In order for any useful work to be done, the executive must be transferred ("loaded") into the memory part of the hardware processor.

When the executive is loaded into memory and started, all of it is resident. Its first duty is to communicate with the person running the system—the operator. The executive simply waits until an operator requests some service, and then it performs that service. In general, such services include loading and starting programs, controlling program execution, modifying or retrieving system information, and setting system parameters. In most systems, these functions are serviced by transient portions of the executive. By being able to move back and forth—between memory and the system device—the transient portion of the executive can make room for programs that need memory space, thereby improving the size-to-performance ratio of the computer. Movements of this sort occur in time spans measured in milliseconds.

The memory resident portion remains in memory to act on requests from the program, which generally include input/output (I/O) services such as file management, device-dependent operations, blocking and unblocking data, allocating storage space, and managing memory areas. In large systems, these services might also include intertask communication and coordination, memory protection, and task execution scheduling.

In some cases, the user can adjust the size of the executive by eliminating features that are not needed in an application environment. RSTS/E, RSX-11M, and RSX-11S are examples of such systems. RT-11 offers several executives of varying size and capability that can be customized to add features. The RSX-11S system executive is always memory resident when the system is operating. In this case, the user concerned with size can remove routines that perform unneeded operations. In general, all PDP-11 operating systems are designed to be flexible enough to operate in a relatively wide range of hardware environments.

System Utilities

System utilities are the individual programs supplied by Digital that are run under

control of the executive to perform useful system-level operations. System utility programs enhance the capabilities of an operating system by providing users with commonly performed general services. There are three classes of system utilities: those used for program development; those used for file management; and those used to perform special system-management functions.

In the first category are the text editors, assemblers, compilers, linkers, program librarians, and debuggers. A whole section of this Handbook is dedicated to programming languages and program development, and another section introduces some utilities—such as editors and screen formatters—that are useful in program development and in other contexts.

File management utilities include file copy, transfer, and deletion programs, file format translators, and media verification and clean-up programs. For more detailed information on these, see the Handbook section on file and data management.

System management utilities vary from system to system, depending on the purpose and functions the system serves. Some examples are system information programs, user accounting programs, error logging, and on-line diagnostic programs.

Interactive Processing Lets You "Talk" to Your Computer.

Interactive processing—as opposed to batch processing—permits "dialogs" between the computer and the user. People typing commands at terminals and getting quick response, and people writing and editing programs at video terminals, are working interactively with the operating system. In batch processing, however, the whole program must be supplied, along with all necessary data, before any response can be obtained from the computer. Note that all Digital operating systems support interactive processing. Some support batch processing, as well.

The basic distinction among Digital operating systems is the processing method each uses to execute programs. The key distinctions among PDP-11 systems are:

- Single-user vs. multiuser
- Single-job vs. foreground/background
- Foreground/background vs. multiprogramming
- Timesharing vs. event-driven multiprogramming

A *single-user* operating system receives demands upon its resources from a single source. It has only to manage the resources based on these demands. As a result, these systems do not require account numbers to access the system or data files. They usually don't protect the operating system from user programs. RT-11 is an example of a single-user operating system.

A *multiuser* operating system receives demands for its resources from many different individuals and/or programs. The system must manage its resources based

on these demands. Several users may want sole control of a device at the same time, for example. The system handles access to the device. In addition, people may be using the system for different purposes, so some privacy must be maintained. As a result, a multiuser system normally has an account system to manage different user's files. RSTS/E, RSX-11M, and RSX-11M-PLUS systems are all multiuser systems, and all provide device allocation control and file accounts. In the case of the RSTS/E and RSX-11M systems, the file account structure is also used to keep track of the amounts of system resources an individual uses. Furthermore, the RSTS/E, RSX-11M, and RSX-11M-PLUS systems extend privacy by protecting individual users at a system level from the effects of any other users of the system.

An RT-11 system can operate in two modes: as a *single-job* system, or as a *foreground/background* system. In a foreground/background system, memory for user programs is divided into two separate regions. The foreground region is occupied by a program requiring fast response to its demands and priority on all resources while it is processing. Process-control and data acquisition application program are examples of these "realtime" applications. The background region is available for a low-priority, preemptable program, for example, doing numerical analysis or program development.

Two independent programs, therefore, can reside in memory, one in the foreground region and one in the background region. The foreground program is given priority and executes until it relinquishes control to the background program. The background program is allowed to execute until the foreground program again requires control. Thus two programs effectively share the resources of the system.

When the foreground program is idle, the system does not go unused. Yet, when the foreground program requires service, it is immediately ready to execute. Input/output (I/O) operations, such as the input of data from the realtime process, or the output of accounting files to the lineprinter, are processed independently of the requesting job to ensure that the processor is used efficiently as well as to enable fast response to all I/O interrupts.

The basis of foreground/background processing is the sharing of a system's resources between two tasks. An extension of foreground/background processing is *multiprogramming*. In multiprogrammed processing, many jobs compete for the system's resources. While it is still true that only one program can have control of the central processor at a time, concurrent execution of several tasks is achieved because other system resources, particularly I/O device operations printing text or waiting for input from a terminal, for example, can execute in parallel. While one task is waiting for an I/O operation to complete, another task can have control of the CPU. Time slicing (see below) can also manage multiprogramming environments.

RT-11 can also support systems of up to seven foreground programs and one background program, all scheduled by priority.

The RSX-11 family of operating systems employs multiprogrammed processing based on a priority-ordered queue of programs demanding system resources. In this case, memory is divided into several regions called partitions, and all tasks loaded in the partitions can execute in parallel. Program execution, as in the RT-11 foreground/background system, is event-driven. That is, a program retains control of the CPU until it declares a "significant" event—normally meaning that it can no longer run, either because it has finished processing, or because it is waiting for another operation to occur. When a significant event is declared, the RSX-11 executive gives control of the CPU to the highest priority task ready to execute. Furthermore, a high-priority task can interrupt a lower-priority task if it requires immediate service.

The RSTS/E and DSM systems also perform concurrent execution of many independent jobs. RSTS/E and DSM, however, process jobs on a *timesharing* rather than an event-driven basis, since this is best suited for a purely interactive processing environment.

In a timesharing environment each job is guaranteed a certain amount of CPU time (a time slice). Jobs receive time one after another, in a round-robin fashion. The system itself manages timesharing processing to obtain the best overall response, depending generally on whether jobs are compute-intense or I/O-intense. The system manager or privileged users can also specify the minimum guaranteed time for a particular job to service, as well as modify its priority.

Operating Systems Can Be Tailored to Your Needs.

System generation is the tailoring of an operating system to your particular hardware configuration and software services. Such structuring is necessary because each installation is unique, and each requires a different combination of the potential capabilities of a system. Your installation, for example, may not have a lineprinter, but may have extra disk drives or expanded memory. It would be wasteful to reserve valuable memory space for the code necessary to run lineprinters; also, you must configure the system so that it can use the disk drive. This is accomplished at system generation (sysgen) time. Some operating systems, such as RT-11 provide several executive options, so that many customers find they don't have to do a system generation at all.

System generation is also the point at which the system manager decides upon the inclusion, allocation, or definition of various utilities and system-wide parameters. In an RSX-11M system, for example, the manager could decide whether both event-driven and time-slice scheduling for realtime tasks should be available.

Finally, some layered software products are "added on" at sysgen time. (Other layered products might have been added after system installation, but before system generation.) If a RSTS/E manager wants to have the PASCAL compiler available to users, for example, it is during system generation that the compiler is added.

Systems may, of course, be resysgened as needs change, as when the system grows, hardware is expanded, or additional compilers are added. Usually system generation is a routine procedure that involves a menu and a dialog between the system and the manager or Digital software specialist. In some situations the sysgen can occur while the system is running; in others it may be necessary to bring the system down for the small time the operation requires.

Data Management Manipulates Binary Information.

Computers deal with binary information. Of course, most people find it inconvenient to "think" in binary codes, so Digital's operating systems are programmed to translate easier-to-understand programming languages into binary. The way in which people interpret and manipulate the binary information is called *data management.*

This section describes PDP-11 software data management structures and techniques, from the physical storage and transfer level to the logical organization and processing level. (For definitions of words you are unfamiliar with, see the Glossary.) Contents of the following sections include:

- ASCII and binary storage formats—how binary data can be interpreted.
- Physical and logical data structures—the difference between how data storage devices operate and how people use them.
- File structures—how physical units of data are logically organized for easy reference.
- File directories—how files are located and retrieved.
- File protection—how files are protected from unauthorized users.
- File naming conventions—how files are identified.

Physical and Logical Units of Data.

Computers—at their most fundamental level—understand only binary information. *Physical units* of data are the elements which computers use to store, transfer, and retrieve binary information. A *bit* (binary digit) is the smallest unit of data that computer systems handle.

In PDP-11 computers, a *byte* is the smallest memory-addressable unit of data. A byte consists of eight binary bits. An ASCII character code can be stored in one byte. Two bytes constitute a 16-bit *word.* Some machine instructions are stored in one word.

The smallest unit of data that a record-oriented I/O peripheral device can transfer is called its *physical record.* The size of a physical record is usually fixed and depends on the type of device being referenced. For example, a card reader can read and transfer 80 bytes of information at a time, stored on an 80-column

punched card. The card reader's physical record length is thus 80 bytes. (Character-oriented devices—paper tapes and terminals—can obviously transfer a single character at one time.)

A *block* is the name for the physical record of a mass storage device such as disk or magnetic tape. An RK05 disk block consists of 512 contiguous bytes. Its physical record length is 512 bytes.

Physical blocks can be grouped into a collection called a device or a physical *volume*. This collection has a size equal to the capacity of the device medium. The term physical volume is generally used with removable media, such as disk packs or magnetic tape.

Logical units of data are the elements manipulated by people and programs to store, transfer, and retrieve information. The information has logical characteristics; for example, data type (alphabetic or decimal, for instance) and size. The logical characteristics are not device dependent; they are determined by the people using the system. It is the job of the operating system to correlate physical and logical data units. This frees the programmer or user from worrying about manipulation, and allows them to concentrate on solving an application problem.

A *field* is the smallest logical unit of data. The field on a punched card, for example, used to contain a person's name is a logical unit of data. It can have any length necessary, determined by the programmer who defines the field.

A *logical record* is a collection of fields treated as a unit. It can contain any logically related information, in any one of several data types, and it can be any user-determined length. Its characteristics are not device dependent, but they can be physically defined. For example, a logical record can occupy several blocks, or it can reside in a single block, or several logical records can reside in a single block. Its characteristics are determined by the programmer. A record, for example, could contain all of the status information about an item in inventory or about a loan applicant.

A *file* is a logical collection of data that occupies one or more blocks on a mass storage device such as a disk or magnetic tape. A file is a system-recognized logical unit of data. Its characteristics can be determined by the system or the programmer.

A file can be a collection of logical records treated as a unit. An example is an employee file containing one logical record for each employee. Each record contains an employee's name and address and other pertinent information. If the logical record length is 50 bytes and there are 200 employees, the complete employee file could be stored in 20 512-byte blocks. Depending on the file structure used in the system, the blocks could be scattered over the disk, or could be located one after the other.

A *logical volume* is a collection of files that reside on a single disk or tape. It is the logical equivalent of a physical device unit (a physical volume) consisting of physical records, such as a disk pack. The files on a volume may have no specific

relationship other than their residence on the same magnetic medium. In some cases, however, the files on a volume may all belong to the same user of the system.

Figure 2-2 illustrates some of the kinds of physical and logical units of data that PDP-11 computer systems handle.

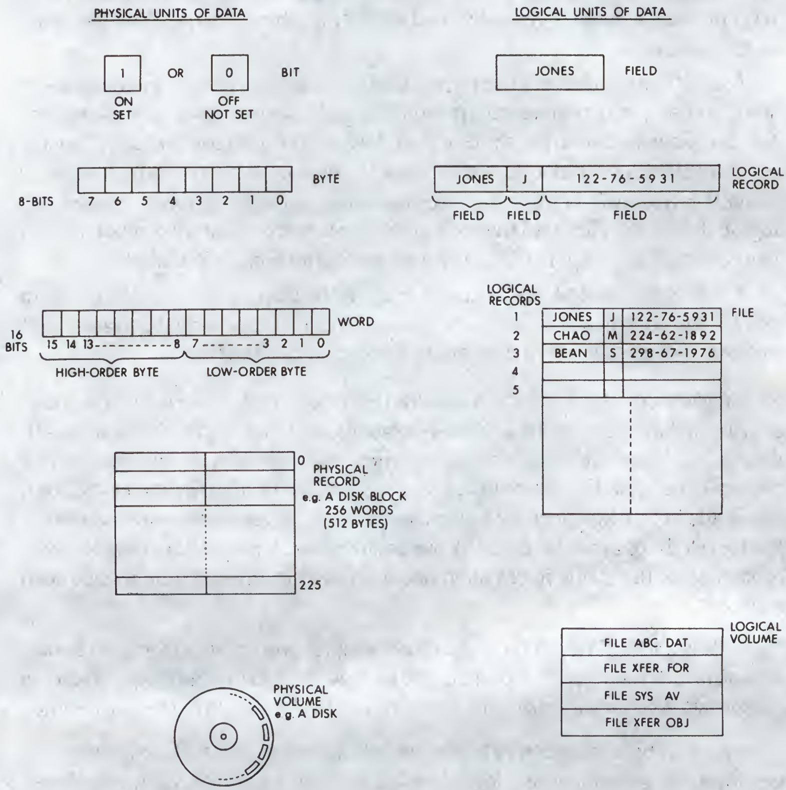


Figure 2-2 Physical and Logical Data Storage

In large, sophisticated systems such as RSTS/E, RSX-11M, and RSX-11M-PLUS, the way in which data are stored on the byte or bit level is rarely a concern of the application programmer. The operating system handles all data storage and transfer operations. In smaller systems such as RT-11, the programmer can become involved in data storage formats, although this is not generally a necessity. A particular application may require the selection of a particular storage format.

Data Storage and Transfer Modes

All PDP-11 operating systems use two basic methods of data storage: ASCII and binary. Data stored in ASCII format conform to the American Standard Code for Information Interchange, in which each character is represented by a 7-bit code. The 7-bit code occupies the low-order seven bits of an 8-bit byte. The high-order bit is normally zero for PDP-11 systems. Text files are examples of data stored in ASCII format.

Binary storage always uses all eight bits of a byte to store information. The significance of any bit varies depending on the kind of information to be stored. Machine instructions (2's complement integer data) and floating point numeric data are some examples of data stored in binary format.

Figure 2-3 illustrates the way in which binary data can be interpreted as either ASCII data or machine instructions. The figure shows examples of a word of storage containing a sequence of bits, interpreted first as two ASCII characters and second as a machine instruction.

The data storage format is related to the way in which data are transferred in an I/O operation.

Formatting can also be applied at a higher level to define the type of data file being processed. In the RT-11 system, there are four types of binary files; each type signifies that a special interpretation applies to the kind of binary data stored. For example, a memory image file is an exact picture of what memory will look like when the file is loaded to be executed. A relocatable image file, however, is an executable program image whose instructions have been linked as if the base address were zero. When the file is loaded for execution, the system has to change all the instructions according to the offset from base address zero.

I/O Devices and Physical Data Access Characteristics

In a PDP-11 computer system, data moves from external storage devices into memory, from memory into the CPU registers, and out again. The window from external devices to the CPU is called the I/O page. Each external I/O device in a computing system has an I/O page address assigned to it. Figure 2-4 illustrates the data movement path in a PDP-11 computing system.

Although all external devices are controlled similarly, devices differ in their ability to store, retrieve or transfer data. Almost all PDP-11 operating systems provide device independence among devices that have similar characteristics and, where possible, between differing devices in situations where the data manipulation operations are functionally identical. Primarily, PDP-11 operating systems differentiate between:

- File-structured and non-file-structured devices
- Block-replaceable and non-block-replaceable devices

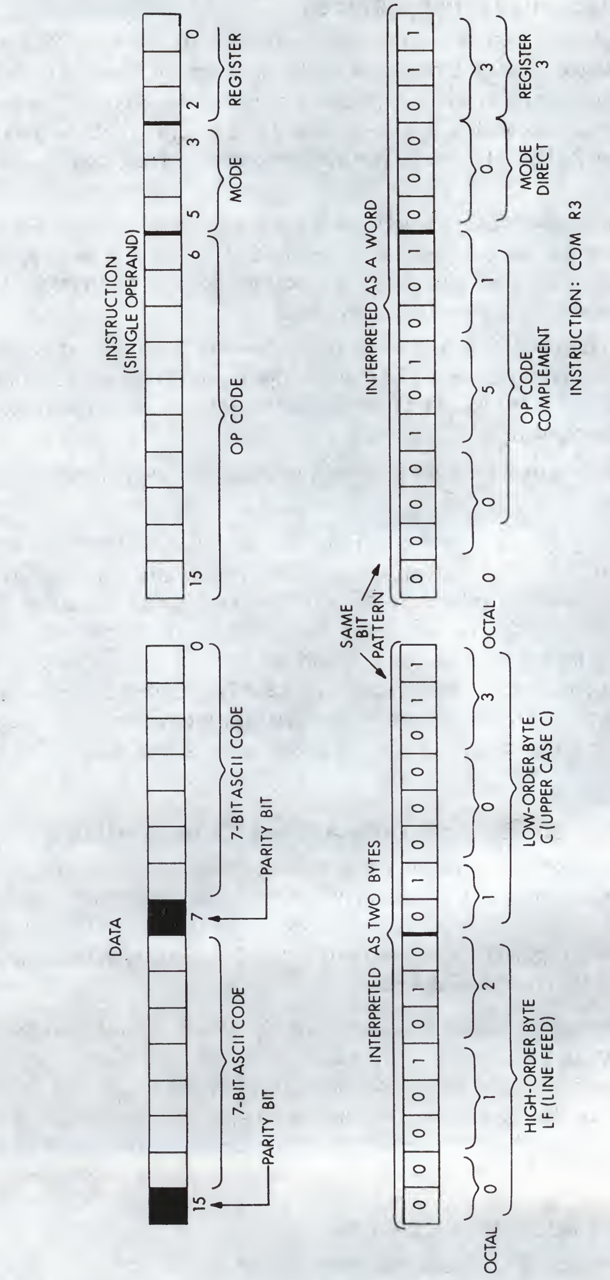


Figure 2-3 ASCII and Binary Storage

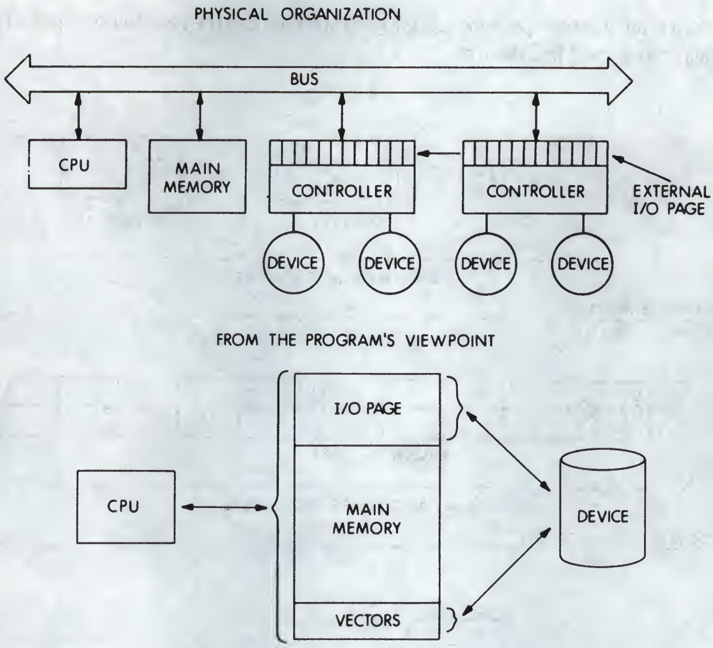


Figure 2-4 Memory and I/O Devices

Terminals and lineprinters are examples of devices that do not provide any means to store or retrieve physical records selectively. They can transfer data only in the sequence in which they occur physically.

In contrast, such mass storage devices as disk and tape have the ability to store and retrieve physical records selectively. For example, an operating system can select a single file from among many stored on the medium.

Mass storage devices are called file-structured devices because a file, consisting of a group of physical records, can be stored on and retrieved from the device. Terminals and lineprinters are called non-file-structured devices because a file cannot be selectively read from or written to them.

Finally, mass storage devices differ in their ability to read and write physical records. Disk devices are block-replaceable devices because a given block can be written without accessing or disturbing all the other blocks on the medium. Magnetic tape is not a block-replaceable device.

A device's physical data access characteristics determine which data transfer methods are possible for that device. Non-file-structured devices allow sequential read or write operations only. Block-replaceable devices allow both sequential and

random read or write operations. Figure 2-5 summarizes the read/write capabilities of each category of I/O device.

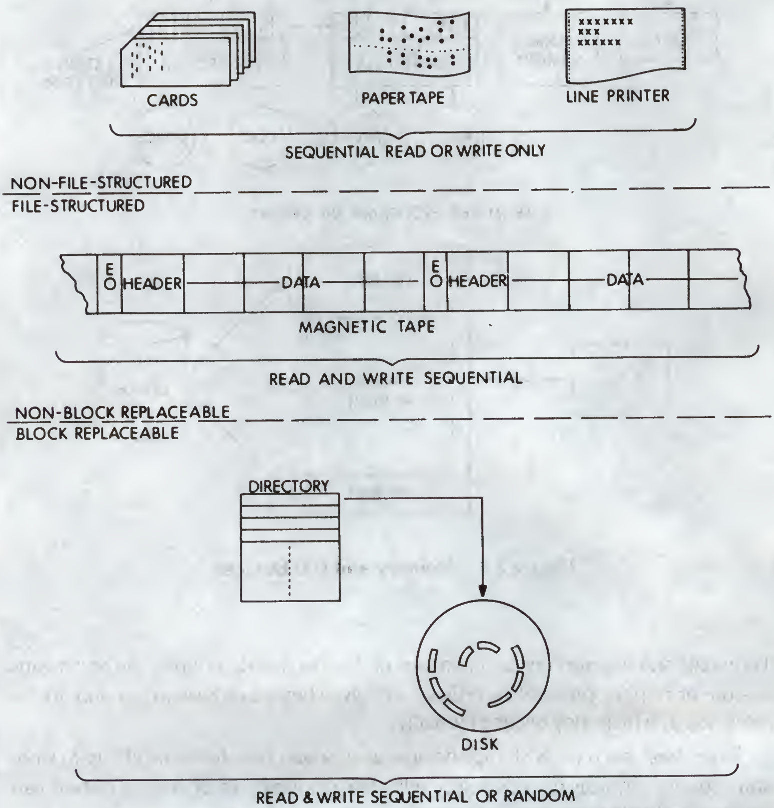


Figure 2-5 I/O Device Read/Write Capabilities

Physical Device Characteristics and Logical Data Organizations

One of the most important services an operating system provides is the mapping of physical device characteristics into logical data organizations. You do not have to write the programs needed to handle input and output to any standard peripheral devices, since appropriate routines are supplied by Digital with the operating system.

There are generally two sets of routines provided in any operating system, depending on its complexity:

- Device drivers or handlers
- File management services

Device drivers or handlers perform operations to relieve the user of the burden of I/O services, overlapping I/O considerations, and device dependence. They can:

- Service I/O devices
- Provide device independence
- Block and unblock data records for devices, if necessary
- Allocate or deallocate storage space on the device
- Manage memory buffers

An operating system can also provide you with a uniform set of file management services. The RT-11 system, for example, provides file management services through the part of the monitor called the User Service Routine (USR), which loads device handlers, opens files for read/write operations, and closes, deletes and renames files.

In summary, an operating system maps physical device characteristics into logical file organizations by providing routines to drive I/O devices and to interface with user programs. Figure 2-6 illustrates the transition between the user interface routines and the I/O devices.

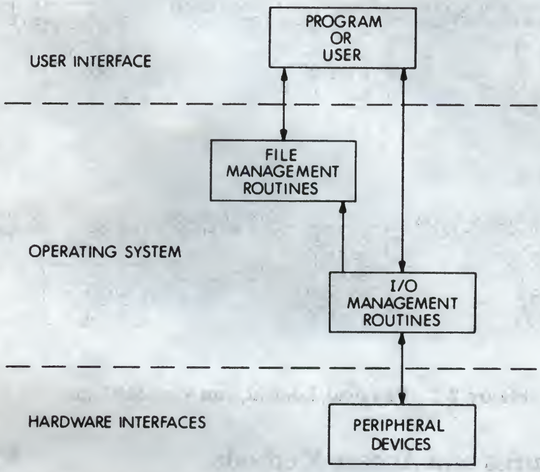


Figure 2-6 Device Control and File Management Services

As an example of the mapping of physical characteristics into logical organizations, the RSX-11 system's device driver and handler and file management services allow the user program to treat all file-structured devices in the same manner. That is, all of these devices appear to the user program to be organized into files consisting of consecutive 512-byte blocks that are numbered from block zero of the file to the last block of the file. In reality, the blocks may be scattered over the device and, in some cases, the device's actual physical record length may not be 512 bytes.

In RSX-11 terminology, the actual physical records on the device (for example, the sectors on a disk) are called physical blocks. At the device driver or handler level, the system maps these physical blocks into logical blocks. Logical blocks are numbered in the same relative way that physical blocks are numbered, starting sequentially at block zero—as the first block on the device—to the last block on the device. At the user interface level, the operating system maps logical blocks into virtual blocks. Virtual block numbers become file-relative values, while logical block numbers are volume-relative values.

Figure 2-7 illustrates the mapping between physical, logical, and virtual blocks in an RSX-11 system. The figure shows two disk device types that have different physical record lengths. In this case, the blocks constituting a file are scattered over the disk. The file is a total of five blocks long. At the logical block level, the operating system views the file as a set of noncontiguous blocks. At the virtual block level, the user software views the file as a set of contiguous, sequentially numbered blocks.

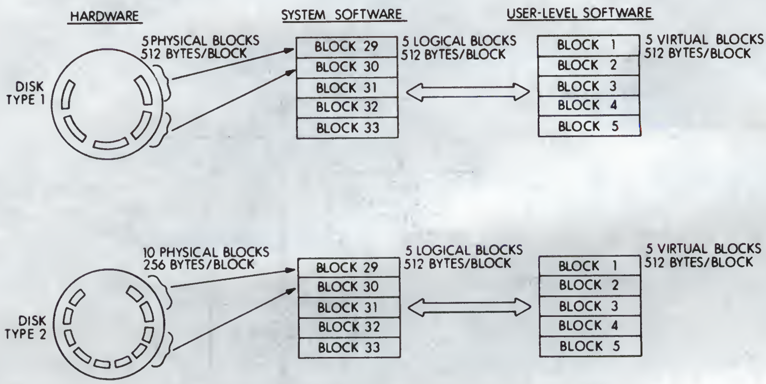


Figure 2-7 Physical, Logical, and Virtual Blocks

File Structures and Access Methods

A file structure is a method of organizing logical records into files. It describes the relative physical locations of the blocks constituting a file. The file structure or

structures that a particular operating system employs is a product of the way in which the system views the particular I/O devices and the kinds of data processing requirements the system fulfills.

File structure is important because a file can be effective in an application only if it meets specific requirements involving:

Size	Growth of the file may require a change in the file structure or repositioning of the file.
Activity	The need to access many different records in a file or frequently access the same file influences data retrieval efficiency.
Volatility	The number of additions or deletions made to a file may affect the access efficiency.

An *access method* is a set of rules for selecting logical records from a file. The simplest access method is sequential: each record is processed in the order in which it appears. Another common access method is direct access: any record can be named for the access. A non-block replaceable devices, such as magnetic tape, can only be processed sequentially. A block-replaceable device, such as disk, can be processed by either access method, but direct access takes greatest advantage of the device's characteristics.

PDP-11 operating systems provide a variety of file structures and access methods appropriate to their processing services. All PDP-11 file structures are, however, based on some form of the following basic file structures:

FILE STRUCTURE	ACCESS METHODS
Linked	Sequential
Contiguous	Sequential or direct access
Mapped	Sequential or direct access

Linked files are a self-expanding series of blocks which are not physically adjacent to one another on the device. The operating system records data blocks for a linked file by skipping several blocks between each record. The system then has enough time to process one block while the medium moves to the next block to be used for recording. In order to connect the blocks, each block contains a pointer to the next block of the file. Figure 2-8a shows the format of a linked file.

Linked file structure is especially suited for sequential processing where the final size of the file is not known. It readily allows later extension, since the user can add more blocks in the same way the file was created. In this way, linked files make efficient use of storage space. Linked files can also be joined together easily.

The blocks of *contiguous* files are physically adjacent on the recording medium. This format is especially suited for random (direct access) processing, since the order of the blocks is not relevant to the order in which the data is processed. The system can readily determine the physical location of a block without reference to any other blocks in the file. Figure 2-8b shows the format of a contiguous file.

Mapped files are virtually contiguous files; they appear to the user program to be directly addressable sets of adjacent blocks. The files may not, however, actually

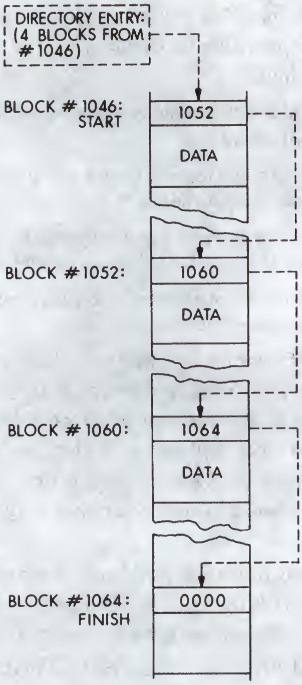


Figure 2-8a Linked File Structure

occupy physically contiguous blocks on the device. The blocks can be scattered anywhere on the device. Separate information, called a file header block, is maintained to identify all the blocks constituting a file. This method provides an efficient use of available storage space and allows files to be extended easily, while still maintaining a uniform program interface. Figure 2-9a illustrates a mapped file format.

If desired, a mapped file can be created as a contiguous file to ensure the fastest random accessing, in which case it is both virtually and physically contiguous.

The basic file structures discussed above can be modified or combined to extend the features of each type for special-purpose logical processing methods. Some examples are indexed files and global array files.

For the most generalized and flexible file structure, you can use indexed files, which are actually two contiguous files. One file acts as an ordered map of a second file containing the target data. The index portion or map contains either an ordered list of key data selected from the target data records or pointers to data records in the second file, or both.

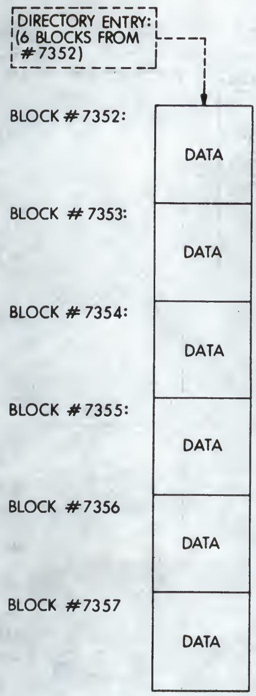


Figure 2-8b Contiguous File Structure

The target data records can be processed in the order of the index portion, or the target data records can be selected by searching through the index portion for the key data identifying the records. These methods of logically processing the target data are called *indexed sequential access* and *random access by key*, respectively.

The Digital Standard Mumps (DSM) operating system provides another special file structure, called *global array files*, a version of the linked file structure. The arrays themselves are a logical tree-structured organization consisting of one or more subscripted levels of elements. All elements on a particular subscripting level are stored in a single chain of linked blocks. At the end of each block in the chain is a pointer to the next block in the chain. The levels of the array (all the block chains) are linked together through pointers in the first block of each chain. This file structure ensures that the time it takes to access any element of the array is minimal. Figure 2-9C shows the DSM global array structure.

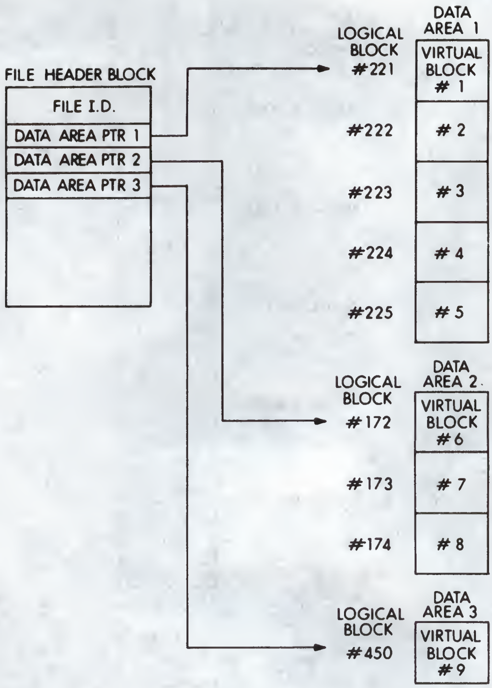


Figure 2-9a Mapped File Structure (Non-contiguous File)

Directories and Directory Access Techniques

Just as file structure and access methods are required to locate records within files, directory structures and directory access techniques are required to locate files within volumes.

A directory is a system-maintained structure used to organize a volume into files. It allows the user to locate files without specifying the physical addresses of the files. It is a direct access method applied to the volume to locate files.

RT-11 supports the simplest kind of file directory. When disk and tape media are initialized for use, the system creates a directory on the device. Each time a file is created, an entry is made in the directory that identifies the name of the file, its location on the device, and its length. When access to the file is requested thereafter, the system examines the directory to find out where the file is actually located. The system can access the file quickly without having to examine the entire device.

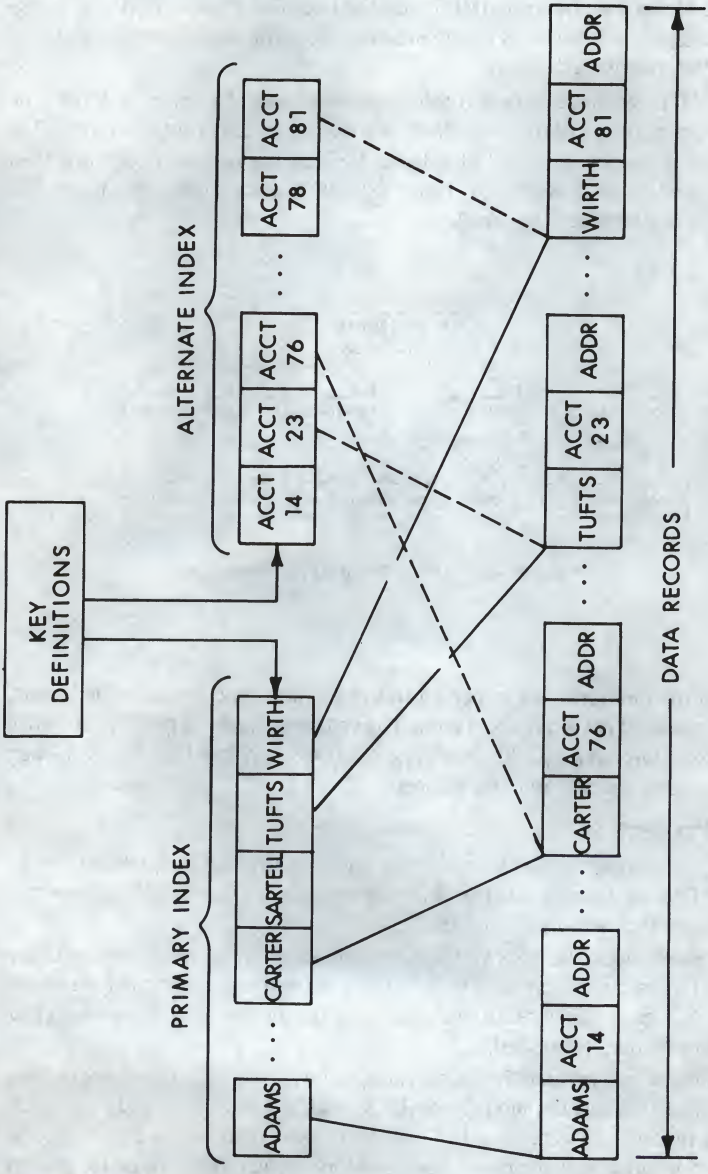


Figure 2-9b Indexed File Structure

In multiuser systems like RSTS/E and RSX-11M, the system uses two different kinds of directories to differentiate between files belonging to different users. They are the Master File Directory (MFD) and the User File Directories (UFD). These directories are maintained as files themselves, stored on the (physical) volume for which they provide a directory.

The MFD contains the names of all the possible users of a particular device. The UFD contains the names of all the files created by a particular user on a device. The system first checks the MFD to locate the UFD for the particular user, and then checks the UFD to locate the file. Figure 2-10 illustrates the use of the Master File Directory and the User File Directory.

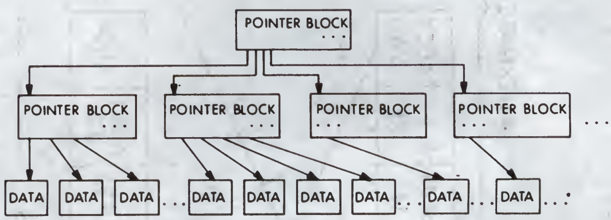


Figure 2-9c DSM Global Array Structure

Though the directories are important in the operation and access of the system, most users need not worry about them. The system maintains directories on behalf of all users. Of course, as with most system services, privileged users may do their own directory creation and maintenance.

File Protection

RT-11 provides the simplest form of file protection with a one-bit "protected" designation. Files so named cannot be accidentally deleted. Under RT-11 no system of user numbers or accounts is needed.

Directories form the basis for file access protection in multiuser systems. Unauthorized users cannot access a file unless they know the account under which it is stored and can obtain access to that account. Account systems and file access protection techniques are related.

Multiuser systems identify the individuals who use the system by account numbers called User Identification Codes (UICs), which are normally assigned by the system manager. In general, a UIC consists of two numbers: the first number is used to identify a related group of users and the second number is used to identify an individual user in the group.

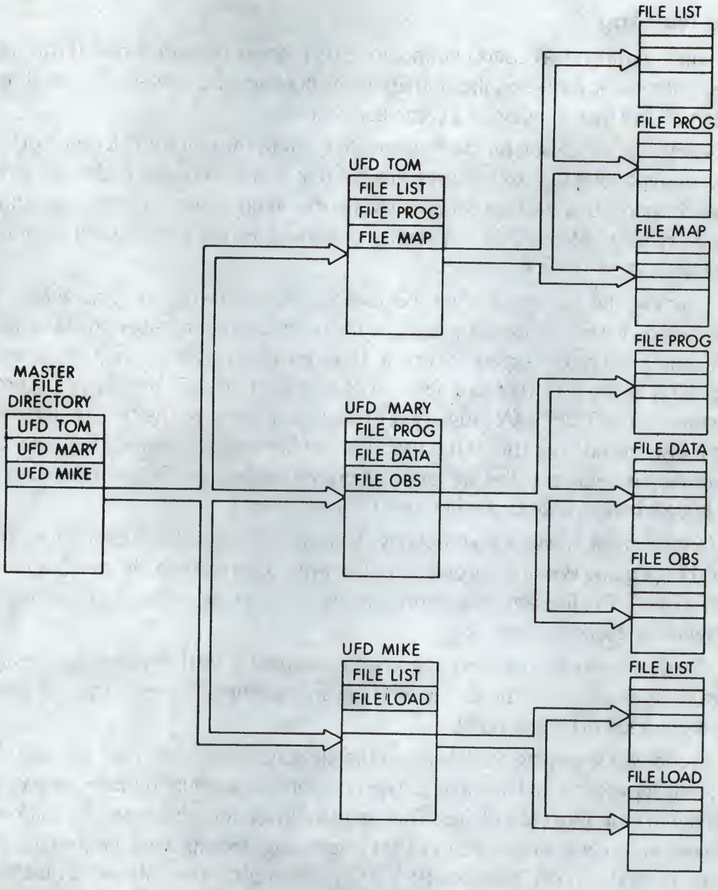


Figure 2-10 Master and User File Directories

The RSX-11 file system provides a protection scheme for both volumes and files. You can specify protection attributes for an entire volume as well as for the files in the volume. A file or an entire volume can be read-, write-, extend- or delete-protected. Distinctions are made on the basis of account number, where the system recognizes four groups of users: privileged users, owner, owner's group, and all others.

In RSTS/E systems, an individual file can be protected against read access or write access where distinctions are made on the basis of the UIC account number under which a file is stored. A file can be read protected, for example, against all users who are not in the same account group and write protected against all users except the owner.

File Naming

The most common way users communicate their desire to process data is through file specifications. A file specification uniquely identifies and locates any logical collection of data that is online to a computer system.

A language processor, for example, needs to know the name and location of the programming language source program file that it is to compile; it also needs to know the name that the user wants to use for the output object program and listing files it produces. Most PDP-11 operating systems share the same basic format for input and output file specifications.

Typically, the file specification includes a device name (given by an abbreviation mnemonic) for the device where the file resides, a unit number, the file name itself, and a file type—a group of one to three characters that conventionally tells what kind of file it is. (For example, .FOR as a file type says the file is a source program in the FORTRAN language.) In multiuser systems, the file specification might also include the UIC of the user and the file version number. If a network application is being run, the file specification would also include the node name of the node where the file is, if other than the host system.

In most cases, the user does not have to issue a complete file specification. The PDP-11 operating systems use default values when a portion of a file specification is not supplied. The filename extension defaults, for example, depend on the kind of operation being performed.

The device name, if omitted, is normally assumed to be the system device, and most systems also allow the user to omit the unit number. If omitted, the unit number is assumed to be unit number 0.

In addition to relying on defaults in the file specification, the user can also put an asterisk in place of a file name, file name extension, account number, or version number to indicate a class of files. The asterisk convention, also called the *wildcard convention*, is commonly used in PDP-11 operating systems when performing the same operation on related files. For example, the file specification DP1:[2,1]PROG.* refers to all files on DP1: under account [2,1] with a file name PROG and any extension. The file specification DK:[*,*]FILE.SAV refers to the files under all accounts on drive unit 0 named FILE.SAV.

User Interfaces Let You Communicate With Your System.

User interface refers to both the software that passes information between a user and a system and the language that a system and a user use to communicate. In the latter sense, a user interface consists of commands and messages. Commands are the instructions that the user types on a terminal keyboard (or gives to a batch processor) to tell the system what to do. Messages are the text that a system prints on a terminal that tells the user what is going on; for example, prompting messages, announcements, and error messages. This section discusses commands— the por-

tion of the user interface that tells the system what to do, and prompting messages— the messages the system prints when it is ready to receive commands or information.

There are basically four types of commands used in PDP-11 operating systems:

- Special terminal commands— which use keys on a terminal for special functions
- Monitor or command language commands—used to request services from the system as a whole
- I/O commands—used to direct any kind of I/O operation (often a part of monitor commands)
- System program commands— used in system programs that perform operations relevant only to the individual program

Since system program commands are relevant only for individual system programs, and not for operating systems in general, this section discusses only monitor and command language commands, I/O commands, and special terminal commands.

Special Terminal Commands

Special terminal commands involve a set of keys or key combinations that, when typed on a terminal, perform special functions. For example, a user normally types the carriage return key at the end of an input command string to send the command to the system, which responds immediately by performing a carriage return and line feed on the terminal. The key labeled RUBOUT or DELETE is used to delete the last character typed on the input line.

The most significant special terminal commands are those used with the key labeled CTRL (control). When the CTRL key is held down (like the shift key) and another key is typed, a control character is sent to the system to indicate that an operation is to be performed.

For example, a line currently being entered (whether as part of a command or as text) will be ignored by the system if you type a CTRL/U combination. You can then enter a new input line. The CTRL/U function is the same as typing successive RUBOUT keys to the beginning of a line. CTRL/U is standard on PDP-11 operating systems.

Another example is the CTRL/O function. If, during the printing of a long message or a listing on the terminal, you decide you are printing the wrong file, you can type a CTRL/O to stop the terminal output. If you wish to stop and then resume output to a terminal, you type CTRL/S to stop it and then CTRL/Q to resume. CTRL/O, CTRL/S, and CTRL/Q are standard functions on PDP-11 operating systems.

Monitor and Command Language Commands

The primary system/user interface is provided in PDP-11 operating systems by either monitor software or special command language interface programs that run under the monitor. The monitor software and command languages allow the user to request the system to set system parameters, load and run programs, and control program execution.

An input command line consists of the command name (an English word that describes the operation to be performed) followed by a space and a command argument. The command to run a program is the word RUN followed by the name of the file containing the program, for example. If the command name is long, it can usually be abbreviated.

In the RT-11 system, a monitor component called the keyboard monitor performs the function of notifying the user that the monitor is ready for input by printing a period at the left margin. The user enters a command string on the same line and terminates the command string by typing the carriage return key.

In the RSTS/E system, there are four keyboard monitors that share the responsibility for interpreting commands: DCL, BASIC-PLUS, RSX, and RT-11. All of these interpret sets of system commands, that is, words followed by optional command parameters. These system commands allow users to perform all the fundamental functions required to use the RSTS/E system, such as logging on and off, and running programs.

I/O Commands

As mentioned above, users communicate their intentions to process data files by issuing I/O commands consisting of at least one file specification. Normally, the I/O commands used in a system are standard throughout that system; in addition, most PDP-11 operating systems share the same basic I/O command string format.

Three command string formats are generally available: Digital Command Language (DCL), the Concise Command Language (CCL), and the older, less convenient Command String Interpreter (CSI) formats. Under DCL and CCL, the command, input, and output file specifications and options may all be entered in a single line in response to the system prompt.

- COPY MYFIL YOURFIL

Omitted information will be prompted for by the system until the command is complete in its general format:

- COMMAND input filespec output filespec/option

Because DCL and CCL use English-like commands and options, they are easy to learn and use.

The older CSI requires several more steps: in response to the system prompt, the user enters a RUN command and the name of a program to be run, e.g., PIP (Peripheral Interchange Program). The response is a command level prompt for file specifications:

- RUN PIP
  * YOURFIL = MYFIL.

The general format, including single-letter switches, is:

- RUN Program
  * output filespec = input filespec/switch

To return to the monitor level, the user types C.

Command string switches are simply ways of appending qualifying information to an I/O command string. The switches used vary from program to program. They are not usually required in an I/O command string, since most programs assume default values for any switch.

Digital Command Language is a quick-to-learn command language that can be used by both interactive and batch-processed jobs for interactive program development, device and data file manipulation, and program execution and control.

Commands are composed of English words; command parameters such as file name specification and options can follow the command on the same line, or can be printed on subsequent lines in response to the system prompt.

In order to make DCL friendlier, Digital has supplied it with extensive facilities that both guide the user on the proper operation of the commands and supply explanations of system messages. In addition, through the use of defaults, DCL relieves users of many routine decisions and much redundant typing in order to complete parameters and options. Of course, the users can override the defaults in any command by using simple command options. Abbreviations also speed up the command typing procedure— users can type the shortest unique form of both commands and parameters. File specifications for DCL can be as simple as the name of the file only, or as detailed as a full listing of network, node device (including type, controller, and unit), directory, file name, file type, and version number.

Though there are more than a hundred DCL commands, users can also program and store commands of their own, and then use them just as the Digital-supplied commands are used.

Digital Command Language is a company standard that makes movement from one system to another easier by providing consistent formats and syntax. It is now available on RT-11, RSX-11M, RSX-11M-PLUS, RSTS/E, and VAX/VMS operating systems.

RT-11's version of the DCL is the set of keyboard monitor commands, whose features include wildcards, factoring (a simplifying method of string replacement), abbreviations, and prompts. Here is a short example of prompting:

```
   COPY/C ONCATENATE
From ?
DX1: (TEST.LST, TESTA.LST)
To ?
DX2: TEST.LST.
```

The system continues to prompt for input and output file specifications until you provide them. Keyboard monitor commands can be collected together into indirect command files.

A Concise Command Language (CCL) command is used to run and pass arguments automatically to designated programs stored in the system library. The programs can be system utilities supplied with the operating system, or can be user-written console routine programs that perform application operations specific to your job.

CCL commands not only provide an easy-to-use command interface, but they can also provide protection from unauthorized use of certain programs. If a particular program performs several operations, some of which should not be available to unauthorized users, for example, the system manager can prevent those users from issuing the RUN command to run the program, but can allow them to perform the safe operation subset by using CCL commands.

In the RSX-11 systems, an additional command interface called the *Monitor Console Routine* (MCR) allows the user to perform system level operations. There are two kinds of commands that MCR accepts: general user commands and privileged user commands. General user commands provide system information, run programs, and mount and dismount devices. Privileged user commands control system operation and set system parameters.

Programmed Requests Provide Access to System Services.

All PDP-11 operating systems provide access to their numerous services through requests that programs or tasks can issue during execution. A *programmed request* inserted directly into the program provides the mechanism.

Under the RT-11 system, MACRO-11 programmers may use programmed requests to perform file manipulation, data transfer, and such other system services as loading device handlers, setting a mark time for asynchronous routines, suspending a program, and calling the Command String Interpreter (CSI).

In the RSTS/E system, users have access to the monitor's services through system function calls. The function calls allow a program to control terminal operation, to read and write core common strings, and to issue calls, in turn, to the system file processor. File processor calls, in turn, enable a program to set program run priority and privileges, scan a file specification, assign devices, set terminal characteristics, and perform directory operations. When the function operation is performed, the program continues execution.

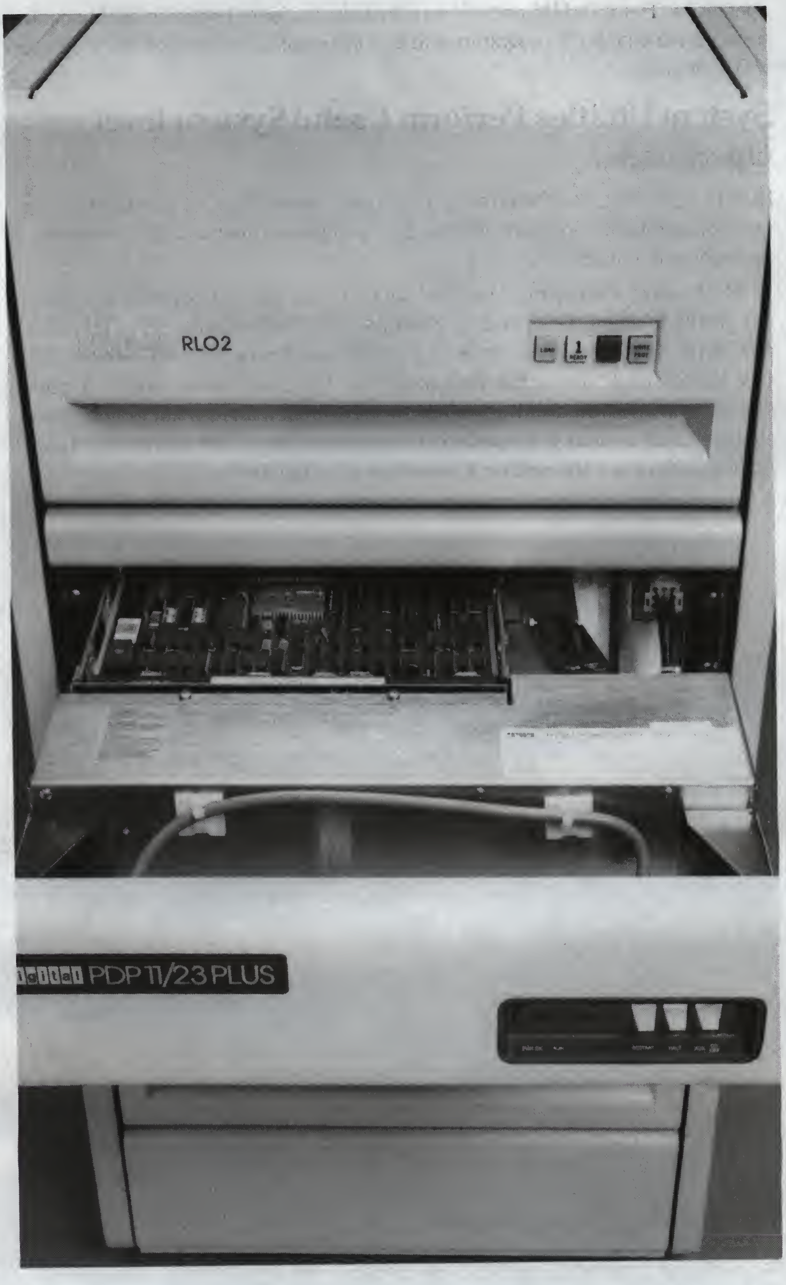
The RSX-11 executive includes programmed services called executive directives. Directives can be executed in MACRO programs using system macro calls provided with the system. The directives allow a program to obtain system information, to control task execution, to declare signficant events, and to perform I/O

operations. The RSX-11M operating system also includes programmed file control services that enable the programmer to perform record-oriented and block-oriented I/O operations.

System Utilities Perform Useful System-level Operations.

PDP-11 operating systems provide, in general, three kinds of system utility programs: program development utilities, file management utilities, and special system management utilities.

Most *system management utilities* included in an operating system are dependent on the function the operating system serves. For example, RSX-11M, RT-11, and RSTS/E include system error logging and report programs. RSTS/E and RSX-11M-PLUS include user accounting programs. The chapters on specific operating systems will give you an idea of some of the system management utilities associated with each system. For details on *file management utilities* and *program development utilities*, see the pertinent sections of this Handbook.


RL02
PDP 11/23 PLUS

Chapter 3

The RSX-11 Family

RSX-11 Offers Upward *and* Downward Compatibility in a Realtime, Multitasking Environment.

Digital offers excellent realtime multitasking with its RSX-11 family of operating systems. Different members of the family are particularly suited to various classes of PDP-11 processors, but there is a high degree of compatibility across the family, so that programs written for one system will migrate easily to other systems. Upward and downward compatibility in the family assure that growth of the installation and changing requirements are easily accommodated.

The RSX-11 family is also appropriate as a base for cross system migration when used with tools such as the Professional Toolkit for the Professional 300 line of personal computers, and the Applications Migration Executive (AME) for VAX/VMS systems.

RSX-11 systems offer:

- Fast response
- Numerous user and system utilities
- A wide range of programming languages
- Management of up to 250 priority levels
- Good program protection
- Low overhead
- Realtime leadership
- Interactive program development and execution
- Multiuser multiprogramming

The high-end RSX-11M-PLUS product can also handle batch job execution.

You can tailor your RSX-11 system to meet the requirements of any application. Of course, as your requirements change, the software can be reconfigured quickly to match the altered situation.

As the pioneer in distributed processing, Digital has made sure that computers operating with RSX-11 can be linked together using the DECnet networking software. They can also be linked via Internets (protocol emulators) to certain computers from other manufacturers. In these ways, regardless of their geographical loca-

tions, tasks can communicate with, supply information to, and control one another. In fact, programs may be developed on one system and then loaded into and run on another. Operators at terminals can control peripherals and processors at other locations in the network.

Highly reliable RSX systems have built-in protection mechanisms in both hardware and software to ensure data integrity and system availability.

The RSX-11 Family Offers a Choice of Systems.

RSX-11 realtime operating systems provide a reliable, high performance environment for rapid response to realtime demands as well as to such less time-critical activities as program development. The RSX-11 family comprises four compatible realtime multiprogramming operating systems: RSX-11M, a compact, efficient operating system; RSX-11M-PLUS, a high performance superset of RSX-11M; Micro/RSX, an extended subset of RSX-11M-PLUS designed for the MICRO/PDP-11; and RSX-11S, a small execute-only operating system for dedicated application environments.

Micro/RSX

Micro/RSX is an extended subset of the multi-user, multi-task RSX-11M-PLUS operating system and packaged on an RX50 mini floppy disk. The newest member of the RSX-11 family, Micro/RSX was designed primarily for use with the MICRO/PDP-11 and is a customer installed, easy to use system that can support up to ten users in both realtime and timesharing environments.

Micro/RSX is offered in two packages. The Base Kit provides the full RSX-11M-PLUS Executive, appropriate utilities and device drivers, support for user-mode program development in high level languages, and a user documentation kit. The Advanced Programmer's Kit is an add-on to the base package and includes the software and documentation necessary for MACRO privileged mode program development. This includes a MACRO Assembler, a Librarian, and system libraries specifically designed for privileged mode programming.

RSX-11M-PLUS

RSX-11M-PLUS is a multiuser system for both program development and application execution designed to run on PDP-11/23-PLUS, PDP-11/24, PDP-11/44 and PDP-11/70 computers. This operating system takes advantage of the expanded memory capability of these machines to provide the most flexibility and best performance of any member of the family.

Unique features of RSX-11M-PLUS include:

- User mode I/D space
- Multistream batch
- I/O request queue optimization
- Performance enhancements
- Dynamic dual path disk support

- Shadowed disk support
- Accounting

RSX-11M

The RSX-11M operating system has a subset of the capabilities of RSX-11M-PLUS and is optimized to run on-small-and-medium sized PDP-11s. It is designed to support factory automation, laboratory data acquisition and control, graphics, process monitoring, process control, communications, and other applications demanding immediate response. Its multiprogramming capabilities permit RSX realtime activities to execute concurrently with less time-critical activities such as program development, text editing, and data management.

RSX-11S

A memory-resident subset of RSX-11M is called RSX-11S. Since a file system is not part of RSX-11S, the file features of its parent, such as checkpointing and data management, are not supported. Instead, RSX-11S is used as a super-efficient execute-only system, generally under conditions where a disk could not safely operate such as on the floor of a manufacturing plant. RSX-11S provides excellent online process control. Because all programs are memory-resident, response is extremely fast. Tasks for an RSX-11S system are developed on Digital computers with an RSX-11M, RSX-11M-PLUS, or VAX/VMS operating system. Such tasks are then loaded into the RSX-11S system image by using a supplied host utility, or an RSX-11S utility known as the On-line Task Loader (OTL), or by down-line loading if both the host and the RSX-11S system have DECnet or the DECdataway running. RSX-11S runs on all PDP-11 computers, from the microprocessor LSI-11 to the high-end PDP-11/70.

Features Common to RSX-11M-PLUS and RSX-11M

- Real time multiprogramming
- Digital Command Language (DCL)
- Generalized command line interpreter
- Memory management
- Cluster library support
- Error logger
- Power failure restart

RSX-11M-PLUS Offers Some Unique Features.

User Mode I/D Space

RSX-11M-PLUS supports separate I/D space hardware. This means that a user task can address up to 32K words of instruction and 32K words of data at the same time, giving a 64K-word total. This simplifies the development and enhances performance of large application programs by reducing the need for overlays.

Multistream Batch

RSX-11M-PLUS has a multistream batch processing capability. The operations personnel can control the number of batch streams that can run. Batch jobs can be submitted by an interactive user, a program, or another batch job. When the number of batch jobs submitted exceeds the number of streams, the remainder of the batch jobs are held in a batch input queue. As with the spool queues, the operator can control the batch job queue by changing job priority, holding a job, or killing a job.

Volume mount commands issued in a batch job can request a generic device such as a disk or specific device unit such as disk-drive unit 2. The batch job waits until the operator satisfies the mount request, while other batch jobs proceed.

I/O Request Queue Optimization

This feature allows request queues for disks to be sorted by cylinder number of the request. The end result is that the average seek length is reduced, improving throughput as much as 30 percent. This is in addition to the enhanced performance already available through overlapped disk seeks.

Performance Enhancements

Overlapped disk seeks on RSX-11M-PLUS allow more disk accesses per unit of time. Communications microprocessors reduce the system load of interprocessor communications. Priority scheduling, the ability to lock tasks in memory, and other controls allow for further performance tuning.

Dynamic Dual Path Disk Support

RSX-11M-PLUS provides dynamic dual path support for RK06/07, RP04/05/06, and RM02/03/05/80 disks.

Shadowed Disk Support

In dual disk configurations, RSX-11M-PLUS supports disk shadowing where all disk information is written to both disks. This results in making each disk an exact duplicate of the other and enables the system to continue processing without interruption when one disk fails.

Accounting

For accounting purposes, the RSX-11M-PLUS system itself creates and maintains records of the use of system resources. These records are kept in an accounting log file.

Using the detailed accounting log records provided by the system, the system manager or a system programmer can establish programs for reporting on the use of system resources and for billing.

Because the users of the system resources are identified in two ways, reports on the use of system resources and bills for the use of system resources can easily be generated in either of two ways: by user name or by account name.

RSX-11M-PLUS and RSX-11M Share Some Common Features, Too.

Efficient Realtime Multiprogramming

Multiprogramming, the concurrent processing of two or more tasks residing in memory, is accomplished by logically dividing memory into several named partitions. Tasks are built to execute in a specific partition; all tasks in a given partition, and all partitions in the system can operate in parallel. A task can be fixed in a partition to ensure immediate execution when it is activated, or it can reside on disk while it is dormant to make memory available to other tasks. This allows a number of programs to run simultaneously and maximizes the use of the central processor.

Digital Command Language (DCL)

The Digital Command Language is a useful tool for establishing and controlling the environment in which a process executes. A command is a request directed from a terminal to the operating system for a specific action. Frequently used strings of commands can be built into command procedures. DCL provides you with an extensive set of commands for:

- Interactive program development
- Device and data file manipulation
- Interactive and batch program execution and control

Generalized Command Line Interpreter (CLI)

The Generalized Command Line Intepreter permits you to write your own CLI as part of your application code without the need for internal operating system knowledge. No privileged "system" code is required for the new CLI implementation. There can be multiple CLIs on one system with the added feature that each terminal can be set for a unique CLI.

Memory Management

RSX-11 systems with hardware memory management provide automatic memory protection. The memory area assigned to a task is protected from other tasks executing in the system. Each task has a specific address range in which to execute. Very large programs can be executed using either disk or memory overlay structures.

The basis of event-driven task scheduling is the software priority assigned by your system manager to each active task. Realtime tasks require top priority on the system resources in order to be served properly. RSX-11 systems provide 250 software priority levels to allow concurrent processing of time-critical tasks, interactive terminals, and background computation. These software priority levels enable the user to compile/assemble, debug, and install tasks without affecting realtime task

response. Software priority levels allow you to optimize central processor use, as well as permit flexible performance options that can be tailored to your application need.

When a significant event occurs (such as I/O completion), the system Executive automatically interrupts the executing task and searches for the highest priority task that is ready to execute. It is possible to have several tasks assigned to the same priority. For part of the priority range, a given task will run until it needs to wait for an event. Then the next task at that priority will start executing. For the rest of the priority range, the tasks are rotated in the queue by a round-robin scheduler on a time-slice basis. The effect is to distribute the processor time evenly so that each task has its own turn at the top of the queue.

Once a task is in memory, the Executive normally allows it to run to completion even if memory is required for the execution of a higher priority non-resident task. An alternative with RSX-11 is to declare a task checkpointable. A checkpointable task currently active in a partition can be interrupted and swapped out of memory to disk when a higher priority task requests the partition. Later, after the higher priority task has completed its execution, the checkpointed task will restart execution where it was interrupted. With the checkpointing feature, more tasks can run concurrently in a given amount of memory, giving greater system throughput.

As an option in RSX-11 systems with hardware memory management, the RSX-11 Executive can dynamically allocate available memory in system-controlled partitions for more efficient use of memory. Effectively, this allows a task to be loaded anywhere there is room for it. The Executive keeps a list of the available areas of memory and loads tasks into it on a priority basis until either the requests are satisfied or there is no memory available in the partitions. When a task terminates, the memory it occupies becomes available again.

Cluster Library Support

With cluster libraries, only the library in use at any point in time is actually mapped to the task address space rather than the simultaneous mapping of all libraries. This leaves more task address space for application code.

Error Logger

The error logger features complete and easy-to-read reports, and includes error logging and reporting of customer-added devices.

Power Failure Restart

Power failure restart is the ability of a system to smooth out intermittent short-term power fluctuations with no apparent loss of service or lost data. Power failure restart also involves maintaining logical consistency within the system itself and the application tasks.

System Use

RSX-11 operating systems provide the facilities needed by users to easily implement efficient realtime applications. The Digital Command Language (DCL) is used for interactive as well as batch processing. DCL is simple to learn and use because it prompts users for missing arguments and provides a HELP facility to aid users who have forgotten command formats. The powerful Monitor Console Routine (MCR) command language, available on all but Micro/RSX, also connects the user to the RSX-11 system. DCL or the MCR command language include initialization commands, status, message, task control, and system maintenance commands. The MCR organization also makes it possible for users to add commands to meet their own special application needs.

To eliminate the need for typing frequently repeated sequences of commands, users can create an *indirect command file*— a text file that contains complete command lines or a series of commands. When the user enters the name of the indirect command file, the system processes the command lines in the file just as if they were being typed successively at the terminal.

Indirect command files also allow system queries, string substitutions, multilevel indirect command files of up to four levels, special symbol definitions, and an extensive number of directives. These directives allow users to:

- Define labels
- Define and assign values to three types of symbols: logical, numeric, and string
- Create and access data files
- Control the logical flow within a command file
- Perform logical tests of internal and system states
- Invoke subroutines
- Determine if an invoked task exited successfully
- Do arithmetic
- Control time-based and parallel task execution

There are two types of indirect command files: indirect task command files and indirect DCL/MCR command files. An indirect task command file is a sequential file containing a list of task-specific commands. Rather than retyping commonly used sequences of commands, you can type the sequence once and store it in a file. The indirect task command file is specified in place of the command line(s) normally submitted to the task.

An indirect DCL/MCR command file contains a list of DCL or MCR commands. It can contain both normal commands and special commands to be interpreted by the processor itself and used to control command file processing.

An RSX-11 installation may have special command-language requirements that neither DCL nor MCR can meet. If that is the case, RSX-11 can easily implement a custom *command language interpreter* (CLI) that is specific to an application.

A CLI is an RSX-11 task that can be written in any RSX-11-supported programming language. Users can write CLIs without knowledge of operating system internals nor the need for a privileged system code. Multiple CLIs can be supported, with the added convenience of each terminal being preset for the desired CLI.

In RSX-11 system multiuser environments, a number of terminals can operate concurrently, with each running its own set of tasks. It is important to maintain data and system integrity in this kind of development and application environment. RSX-11 has user identification codes, privileged and nonprivileged accounts, password protection, and separate user directories; such multiuser protection allows the monitor and control of individual users of the system.

To reduce waiting time and accommodate more active terminals, RSX-11 provides print spooling. Print spooling allows programs to run to completion at full speed with print data going to a disk and without tying up memory resources waiting for the lineprinter. When a spooler finishes a job, it automatically selects the highest priority job from the queue for printing.

Under RSX-11M-PLUS, and as an additional option under RSX-11M, there is spooler support for multiple printers and print queues. Users of these systems do not have to compete with one another for access to the printer.

Program Development Tools Shorten the Development Cycle.

RSX-11 has a comprehensive selection of application tools designed to shorten the program development cycle. Using the programming languages and the system utilities, users write, test, and execute programs quickly, interactively examine and evaluate the results of program execution, and modify and tune programs online. Compared to batch, interactive program development and testing is much faster and easier. If you are familiar with batch program development, you will be impressed with the ease of these interactive techniques.

RSX-11 Programming

RSX-11 systems offer an impressive range of programming languages so users can select the right language for their specific applications. For example, an organization that uses RSX-11 for a realtime process control application might use the same system to account for its Work In Process (WIP). The process control application could be written in FORTRAN IV, while COBOL might best suit the WIP program.

MACRO, a powerful assembly language supplied with RSX-11 systems, processes source programs and produces a relocatable object module. Its extensive features allow a programmer to code directly and efficiently in assembly language. Programmers can define individual macros that describe entire sequences of operations: the macro definition is required only once, but the operations can be used repeatedly in any program, simply by invoking the macro.

Digital provides, under separate license, a complete series of higher level languages for RSX-11 systems. They are FORTRAN 77, the primary realtime language;

easy-to-use BASIC-PLUS-2; COBOL81, the language for commercial applications; DIBOL, Digital's business-oriented language; PASCAL; and CORAL 66, a British government-prescribed language.

RSX-11 Has a Powerful Editor and a Wealth of System Utilities.

With these RSX-11 system features, users can create and edit source program files and data files, share programs and routines, and perform general system activities. RSX-11M and RSX11M-PLUS systems give users:

- A powerful text editor, EDT
- A sophisticated task builder (TKB) to link modules and prepare executable programs
- System library routines to reduce program development time
- An optional FMS-11/RSX Forms Management System
- Online debuggers (ODT) that allow users to examine, alter, search, and execute programs
- Record and file management utilities (RMS and FCS)

EDT

EDT is the standard editor offered on most of Digital's operating systems. It is easy to learn, with editing instructions consisting of English words or their shortest unique abbreviations. Extensive HELP facilities remind you quickly of the possible options for a particular command and of the format for that editing instruction. EDT doesn't modify the input file directly, so that if a user accidentally deletes a large amount of text, the original input is still available for quick recovery.

TKB Task Builder

The task builder creates loadable memory images from assembled or compiled tasks. It links relocatable object modules and resolves any reference to global symbols, common areas, and shared libraries. The task builder is used to specify a task's attributes, such as checkpoint-ability, priority, etc. The task builder is also used to create shareable commons. It provides an overlay descriptor language to construct task overlays. The overlay descriptor language simplifies the process of dividing tasks into overlaid segments and specifying load methods. If it is requested by the task-build command, the user can obtain a cross reference of all global symbols defined or referenced in the task. The task builder also has the capacity to link an unlimited number of library files and up to seven virtual memory areas.

Librarian (LBR)

LBR provides the capability to create and maintain disk-resident libraries of object modules and user-defined macros. In addition, LBR may be used to create and maintain *universal libraries* (that is, libraries with entries that may be any files legal under FILES-11: ASCII files, object files, executable task images, for example.)

ODT Online Debugger

ODT aids the user in debugging programs that have been assembled or compiled and task-built. From the keyboard, the user interacts with ODT to:

- Print or change the contents of a location in the task
- Run the program using the breakpoint features to halt the program at specified points
- Search the program for a specific bit pattern
- Calculate offsets for relative addresses

Trace capability is also provided to aid in the debugging of FORTRAN programs.

Data Management Services

Data management services help you to better manage and work with the information in the computer system. RSX-11M and RSX/11M-PLUS data management includes:

- FILES-11, a file system that provides volume structuring and protection
- File Control Services (FCS) and Record Management Services (RMS) that have a variety of access modes for file storage, retrieval, and modification
- A record management services query language—DATATRIEVE

Each of these services has a more detailed description in a later chapter of this book, but each has a short description below.

FILES-11

FILES-11 oversees the storage and handling of both user and system files on volumes. Each volume contains its own set of file directories and information on the protection, size and location of the files on the volumes. The FILES-11 files can be manipulated with system utilities or user-written tasks.

FCS and RMS

The File Control Services (FCS) and Record Management Services (RMS) extend the programming languages by providing general-purpose file and record handling capabilities. They enable a programmer to choose the file organization and record access method appropriate for the data processing application. The file organization and record access methods are independent of the language in which they were programmed.

FCS, the basic file handling system on RSX-11M and RSX-11/M-PLUS systems, treats logical records as data units. These units can be retrieved from a file without requiring the user to know the format in which they were written. FCS supports sequential and random file access.

RMS, a superset of FCS, is compatible with FCS-written files. It adds important capabilities at a level above that of traditional file management services. RMS permits relative, sequential, and multikey indexed sequential file organizations. RMS allows the access mode to be sequential, random, or according to Record File Address.

BRU Backup and Restore Utility

BRU is a high-performance, powerful backup/restore utility. For example, it can copy a 200 MByte RP06 disk to tape in less than an hour. BRU also supports incremental backups (such as backing up only the files that have been modified since the previous backup), which greatly reduces the amount of time required for proper disk backup.

BRU transfers files from a volume to a backup volume (or volumes), to ensure that a copy of the files is available in case the original files are destroyed. If the original files are destroyed, or if for any other reason the copy needs to be retrieved, users can restore the backup files with BRU commands. Users can run BRU either at the same time as other tasks or stand-alone.

Backup and restore operations that take place on disk and tape volumes are:

- Disk to tape—for backup operations
- Tape to disk—for restore operations
- Disk to disk—for either backup or restore operations

In addition to these basic data transfer functions, BRU provides command qualifiers to:

- initialize disks
- perform selective backup and restore operations
- control such tape processing as density, length, ANSI tape labelling, rewinding, and appending
- perform data and volume checking
- display such information as backup set names and file names

BRU reallocates and consolidates the disk data storage area. It concatenates (connects in a series) files and their extensions into contiguous blocks whenever possible, and it can reduce the number of retrieval pointers and file headers required for the same files on the new disk volume.

A BRU operation begins with data on a disk and ends with the same data on another disk, in compressed form.

Maintenance Utilities Modify Programs.

Program maintenance includes modifying, patching, and comparing files. The four program maintenance utilities are the *Peripheral Interchange Program*, the *Source Input Program*, the *Task Patch*, and the *Object Manual Patch*.

PIP Peripheral Interchange Program

PIP is used to copy files from one device to another, from disk to printer, for example; to rename files; to list files; and to delete files.

SLP Source Input Program

SLP is a noninteractive editing program used to create and maintain source language correction files on disk.

ZAP Task Patch

ZAP provides a facility for examining and modifying task image files and data files. With ZAP, permanent patches can be made to task image or data files without having to recreate the file.

PAT Object Module Patch

PAT allows patching or updating code in a relocatable binary object module.

Optional Layered Products Make the Job Easier.

A number of optional layered products are available for RSX operating systems that aid in inquiry and response, as well as data retrieval and updating. Among these are the *Forms Management System* and *DATATRIEVE.*

The Forms Management System (FMS-11/RSX) makes it easier for your application programmers to interact with users by letting them create applications for handling user inquiry or response that are displayed as forms on terminal screens. The forms are easy to read, simple to fill in, and the data are moved quickly and efficiently through the application and the system.

DATATRIEVE is an inquiry language that provides rapid extraction and updating of data from RMS files. Users can also generate reports and create a directory containing command procedures. In order to perform query, display, report writing, and other activities, DATATRIEVE uses a special command language, with simple English-like commands designed to be easy for anyone to use.

Cross Development and Migration Capabilities Aid in Upward and Downward Mobility.

In order to allow for migrations of applications between PDP-11 family members, VAX Systems, and the Professional 300 series, tools have been developed that emulate RSX in those non-PDP-11 environments. These tools include the Professional Tool Kit for the Professional 300 series of personal computers and the Applications Migration Executive (AME) for VAX/VMS.

Professional Tool Kit

The Professional Tool Kit is designed for organizations that want to create software products for the Professional 325 and 350 personal computers. The Tool Kit provides a total software development environment that supports features with the utilities and processing power of PDP/11 and VAX minicomputers. The Tool Kit's development environment spans two computer systems— a host computer and a programmer's personal computer. The host computer is either a PDP-11 with an RSX-11 operating system, or a VAX/VMS. The programmer's personal computer is a Professional 350 with a Winchester disk option. Software for the Professional and for the host system completes the development environment.

The software components that reside on the host system include:

- Professional Development Languages—expanded to support features accessible by CALL statements to the appropriate library routines.
- Frame Builder—an interactive, forms-based utility for creating menus, online help, and message frames. It helps programmers write applications using a consistent interface with the keyboard and display screen.
- RMS/Professional—a powerful set of service routines that provide efficient and flexible data storage, retrieval, and modification.

Applications Migration Executive (AME)

This facility allows most nonprivileged RSX-11 tasks to execute on a VAX/VMS system with little or no modification to the task image. AME is part of the VAX/VMS system. It supports a mapped RSX-11M environment (without supporting the directives to manipulate Program Logical Address Space, or PLAS), DECnet calls, or RMS-11 file sharing. Under AME, the user's task is mapped into virtual memory and executes in compatibility mode. When the task issues an RSX-11M executive directive, a trap is initiated that automatically places the processor in native mode. The AME then determines what directive the user is attempting to accomplish, and executes a VAX/VMS system service of equivalent function. If there is no equivalent function, the executive will return an error code but will not cause the task to abort. Since the system environments differ, applications that involve cooperating tasks may require modification.

Hardware Interfaces Connect Realtime Systems to Your Computer.

For applications handling a wide range of realtime processes—whether you need high speed data acquisition, fast response, monitoring and control of online processes, or the rapid reply to terminal inquiry—the flexible and powerful RSX-11 operating systems can do the job well.

To accommodate a wide range of uses, Digital complements its RSX-11 systems with a comprehensive selection of off-the-shelf interfaces that connect real-time or communication equipment to the PDP-11.

Ready-built for communication, industrial, and laboratory applications are asynchronous and synchronous interfaces, interfaces for analog-to-digital and digital-to-analog conversions, and interfaces for digital input/output. And, if you need to, the RSX-11 operating systems provide a solid foundation and the tools needed to build your own interface.


RD51

Chapter 4

RSTS/E

RSTS/E Provides Interactive Timesharing for a Wealth of Applications.

RSTS/E is a multi-user, general purpose timesharing system that reflects over a decade's careful growth and development by Digital. Many thousands of timesharing customers, from financial institutions and schools to manufacturers, insurance companies, and airlines, find RSTS/E a "blue chip" system: reliable, stable, friendly, and forgiving.

Up to 127 concurrent terminal users in both local and remote locations can interact with multiple application tasks through multiterminal services—and up to 63 without multiterminal services. Tasks can share computational, storage, and input/output services provided by the RSTS/E system.

RSTS/E runs on a variety of Digital processors, accommodating the complete range of peripherals, hardware and add-ons that any customer might need. RSTS/E is well-adapted to the growth of an individual system—as hardware and software are added—and is fully upward- and downward-compatible for applications being migrated across RSTS/E systems.

RSTS/E allows concurrent word processing and data processing using DECword/DP and can also communicate with stand alone word processors. Its built-in and layered functions reflect a Digital commitment to keep the system easy for naive users and yet extremely powerful for users who want to write complex or innovative programs.

Excellent communications software available for RSTS/E lets the computer link into distributed networks of Digital computers (DECnets) or into flexible Internets with computers from other manufacturers. Also, thanks to the availability of a DCL subset with RSTS/E, there is increased compatibility among RSTS/E, VMS, and RSX operating systems.

System accounting facilities included with RSTS/E give the system manager a detailed record of who used the various processor modes and for how long, so that both system management and billing for timesharing time can be done accurately.

There is an enormous amount of specialized software available for customers, from Digital and from commercial developers who specialize in writing program packages for RSTS/E users in numerous industries. Resources of this sort help every customer who needs to enhance the operating system with software designed for financial accounting and general ledger, billing, forecasting, business simulation, materials control, a variety of banking transactions, freight tracking, insurance claim processing, and hundreds of additional timesharing applications.

Micro/RSTS is a compact subset of RSTS/E designed for the MICRO/PDP-11. It's an application-only time-sharing operating system capable of running, but not developing, programs.

Features of both RSTS/E and Micro/RSTS systems are listed in the pages that follow. All have as their goal the creation of a programming environment highly "available," so that programmer productivity is maximized, down-time is reduced to a minimum, and system operations are easy to learn and manage. RSTS/E provides excellent security, particularly useful in sensitive business applications such as bank transactions and stock transfers, where access to certain data must be severely restricted; or for educational institutions in which novice users must be prevented from bringing the system down by inexperience or intent.

Interactive Timesharing Provides Fast Response Time.

Because computer hardware can really do processing of only one program or task at a time, it is important to determine, based upon the uses to which a computer is to be put, how that central processor is to be allocated. In timesharing environments, the processor is scheduled—usually in a round-robin fashion—among all the jobs that want it and are ready to do useful work. There may be levels of priority in timesharing so that, for example, agents who are confirming hotel reservations get served ahead of clerks who are doing inventory control programs; but every timesharing system accounts for all executable programs eventually.

From the user's point of view, the most important timesharing parameter to consider is computer response time, which is the time that elapses between entering an instruction or field of data and the computer's response—computation, a ledger entry, an output operation to a printer or terminal.

RSTS/E systems provide excellent response time to users, who can number up to 127 at one time, and to jobs, which can number up to 63 at one time. A typical mix of users would include some people doing program development and working in a very interactive mode with the computer, some clerks doing data entry for delivery schedules or invoicing, some sales people entering transaction information, and perhaps even a batch job or two being run to complete the weekly salary. In addition, another computer owned by the company might be providing delivery status information via DECnet, or a mainframe from another computer manufacturer might be linked through Internet software from Digital.

With such a diverse mix of users, we might find some people who know very little of the internal working of the computer, some who are programmers and expert in a language like COBOL or BASIC-PLUS-2, and some who are system-level programmers and system managers, capable of adapting the software to a variety of specific needs and of tuning the operating system for maximum performance. Under RSTS/E, all will get excellent response time, and all will feel as though they have unique control of the central processor and other resources of the computer.

RSTS/E tries to keep the CPU busy by running several jobs concurrently. Each user program be it a system utility, run-time system, or application program is a job. A job runs until it either enters an I/O wait state or exhausts its time quantum. At that point, the scheduler finds the next ready job and begins running that job. Meanwhile, the interrupt-driven I/O device handlers are processing requested data transfers. Upon completion of a transfer, the scheduler marks the job that requested the transfer as ready to run again and starts it from the point at which execution ceased.

RSTS/E attempts to keep as many jobs in memory as possible. When more memory is required to run a job than is available, the system temporarily swaps some jobs out of memory and stores them in a swap file. When it is the job's turn to run again, the job in the swap file is brought back into memory. Jobs waiting for more CPU time or keyboard input are most likely to be stored in the swap file, while jobs currently running or involved in disk or magnetic tape data transfers are necessarily in memory.

As the system processes each job, it maintains accounting information concerning that job. When the user logs off the system, all the information accumulated for all the jobs run by the user is used to update the accounting information stored on disk for that user account. This is particularly important to systems in which time is billed among various users.

To begin a timesharing session, a user logs into the system by entering an account name and a password (these are assigned by the system manager, the password is agreed jointly by the system manager and the user). The terminal is then under control of the keyboard monitor of the system default run-time system. The recommended default run-time system is DCL.

Whatever the default run-time system is, after the log in verification is complete and the system messages have been displayed, the user is in command mode. Each run-time system identifies itself by an identifying prompt. These are:

- DCL "$"
- RSX ">"
- BASIC "Ready"
- RT-11 "."

Commands are issued to the keyboard monitor of the run-time system. These commands cause the execution of Commonly Used System Programs (CUSPs) or application programs. The user is permitted to execute all the commands available to a non-privileged user. Privileged users have additional commands available for system management and maintenance.

A privileged user can detach the running job from the terminal, and run another job. The detached job continues to run unattended, but is still associated with the account number under which the user logged in. To retrieve control of a detached job, the user can log in on any free terminal and attach that job to the terminal.

The use of BASIC-PLUS is an important feature of the RSTS/E system. BASIC-PLUS can be run either from any default run-time system by issuing the BASIC command or it can be a run-time system itself. When BASIC-PLUS is entered it is in edit mode, to which it returns when program execution is completed or whenever a CTRL/C is typed. In edit mode, BASIC-PLUS examines each line typed by the user and determines whether that line is:

- A system or installation defined command
- An immediate mode statement
- A program statement

System and installation defined commands are executed immediately after being entered; immediate mode statements are first translated into an intermediate code, (placed in the user's job area) and are executed immediately by the run-time system. Program statements (lines of ASCII text preceded by the line numbers) are stored in their ASCII form in a temporary disk file under the user's account. Program statements without line numbers are immediately executed and not stored. This feature is provided for program debugging.

A user's job area is initialized by either executing the BASIC command or by logging in and being given a size of 2 KB or 4 KB, depending on the run-time system being used. The job area can grow in increments of 2 KB to a maximum size chosen by the system manager. When the user enters program statements in the edit mode, intermediate code created in the user's job area is not executed automatically. A copy of the intermediate code of the program can be transferred to disk storage or to an external storage medium.

You can change from edit mode to run mode by typing the RUN system command or the CHAIN immediate mode statement. In RUN mode, the run-time system interpretively executes the intermediate code stored in your job area. When a program finishes execution, the terminal returns to edit mode as signaled by the printing of the prompt "Ready". You can interrupt the BASIC-PLUS program by typing CTRL/C, which also returns the terminal to edit mode.

Resources Provide the Services You Want From an Operating System.

Since high programmer productivity was an aim of Digital in producing RSTS/E, the features of an easy, forgiving environment are included with the system. User commands to the RSTS/E system are handled and interpreted by one of the run-time systems capable of acting as a keyboard monitor. The most popular languages for business and educational applications are available, including BASIC-PLUS, BASIC-PLUS-2, COBOL-81, FORTRAN-77, FORTRAN IV, and DIBOL. This choice of languages lets you adapt your language to the function at hand, and lets you tap programming talent already trained in these popular languages. If you are familiar with traditional batch-mode program development requirements, you will be

impressed by the ease and speed of developing applications under a RSTS/E system.

Text editors, particularly the Digital standard editor (EDT), help speed program development and correction. EDT is a text editor that can be used to create a file, enter, and manipulate text in the file, and save or delete work done during edit sessions. It is easy to use and when used with Digital's terminals provides full screen video editing capabilities. In actual applications, the RSTS/E user can take advantage of features such as Record Management Services (RMS), software that supports building and accessing sequential, relative, and multikey indexed sequential file structures, and relieves programmers of many tedious tasks of I/O management. Calls from most of the various programming languages to RMS are sufficient to invoke the utility or access method desired.

FMS-11/RSTS Forms Management System is a software package that provides sophisticated screen formatting for application programs. FMS-11/RSTS allows non-programmers to design forms interactively on the video screen and eliminates tedious editing and recompiling of a forms program. The keypad-operated editor and the HELP facility are easy to learn. FMS-11/RSTS provides extensive field protection and validation features that help prevent data errors caused by typing errors.

Other features are described in more detail in sections that follow, and will be of interest to readers who want to know exactly what is available with RSTS/E, and what services it provides to users.

Dynamic Allocation of System Resources Lets *All* Users Receive a High Level of Service.

RSTS/E users can expect efficient operation because the operating system dynamically allocates processor time, memory space, file space, and peripherals to best suit changing demands. The system manager and designated privileged users have access to the RSTS/E system management commands either interactively using system utilities or under program control. Additional system commands and utility programs are also available to all users.

The RSTS/E file system provides a wide range of online processing capabilities. Files can be accessed randomly or sequentially, either through one of the keyboard command or utility programs or through the RSTS/E file system. Files can contain alphanumeric string, integer numeric, floating point numeric, or binary data; they can be created, updated, extended or deleted interactively either from the user's terminal or under program control, and can be sorted by the SORT-11 program. Files can be protected from access on an individual, group, or system basis; they can also be accessed by many users while being updated online.

Total or selective file back-up and restore can be done online without disrupting users, or it can be done during periods when timesharing or application processing

is not permitted. Private disk volumes may be used to limit user access. Removable disk media permit safe storage of valuable records at sites remote from the system.

RSTS/E is a high performance system, and it includes a variety of user tools to tune applications to perform even better. For example, with software disk caching (unrelated to CPU memory caching, which is also available), blocks of heavily used disk data are held in main memory to reduce the number of disk accesses. In addition, heavily used program segments can be held resident in main memory and shared among programs, saving memory space, reducing swapping time, and thus increasing performance. RMS data management code can also be shared for further memory savings. Use of common, shared, resident RMS also results in substantially reduced disk accessing for overlays and thus improves applications performance.

Command Languages Let the System Perform Predefined Operations.

A *command language* is the vocabulary used by a program or set of programs that direct the computer system to perform predefined operations. RSTS/E uses three such command languages, the *User Command Language*, the *Digital Command Language*, and the *Concise Command Language*.

User Command Language

The command language interpreter is interactive, comprehensive, easy to use, and very flexible. It enables the user to log into the system, maniupulate files, develop and test programs, and obtain system information.

The four standard keyboard monitors are DCL, BASIC-PLUS, RSX, and RT-11. All of these interpret sets of system commands, that is, words followed by optional command parameters. These system commands allow users to perform all the fundamental functions required to use the RSTS/E system, such as logging on and off, and running programs.

Digital Command Language (DCL)

The DCL feature is based upon the DCL available on most PDP-11 and VAX/VMS operating systems. It is a subset of the DCL implemented on VAX/VMS. DCL is implemented as a run-time system or as an additional keyboard monitor. Its command set gives the user access to most RSTS/E system features.

Concise Command Language (CCL)

The RSTS/E system commands issued by the user at a terminal are familiar words or abbreviations. The system accepts both long and short command formats for inexperienced and experienced users. It responds with understandable statements and, if a command does not supply complete information, prompts the user for remaining data. CCL commands allow you to enter one command that runs a system utility and specifies a single command for the utility to execute. The number of CCL commands that can be defined varies from system to system, depending on

the number of "small buffers" configured into the system. An average system probably includes a fairly standard set of CCL commands for certain RSTS/E utility programs. The system manager has the option of freely adding to, deleting from, or modifying the standard set of CCL commands.

System Software Extends and Enhances the Capabilities of the Hardware.

RSTS/E system software exists as system code, language processing code, and system program code. The system code and language processing code are tailored at system generation time according to the hardware configuration on which the system runs and the software features which are chosen by the system manager. Once the system is generated, the system code and language processing code are frozen, and are alterable by patching or generating new code. The system program code exists in a library of programs executable by the system software or by individual users on the system. The library of programs is alterable and expandable during timesharing without requiring regeneration of the system.

System Code

The RSTS/E system code is stored on the system disk as a save-image library (SIL). A SIL, when loaded into memory, is immediately executable by the PDP-11 computer. The system code comprises many distinct elements that are either resident in memory or on disk during timesharing. Permanently resident elements are the following:

- Interrupt and trap vectors
- Small and large system buffers
- System information and data tables
- Disk and device drivers
- File processor modules

Optionally, the following are also resident modules:

- FMS/RSTS forms code in the terminal driver
- DECnet/E—Network Communications handler
- RJ2780—Remote Job Entry handler

The following elements are either permanently resident or disk resident (overlay) elements, the choice to be selected during system generation:

- File processor modules
- Infrequently used utility routines

System initialization code is loaded only during system start-up.

RSTS/E operations start when the system disk is bootstrapped. The bootstrap routine loads the initialization code that determines the hardware configuration

and performs many consistency checks to ensure the integrity of the software. When checking is completed, the initialization code remains resident and allows many options.

Language Processing Code

DCL serves as the recommended default run-time system. However, any of the languages mentioned above may be used for applications programs. The auxiliary run-time system or object time system associated with a given language processor is loaded into memory only when a request is made to execute that language compiler or to execute a compiled program written in that language. The language processors reside on the system disk in machine executable form and can be either permanently resident in memory or temporarily resident (swappable). Usually the language compiler is swapped out to disk as required, just as any normal user job would be.

The run-time system may vary in size from 4 KB to 32 KB, and is generally shared among users.

System Program Code

A library of programs is produced and stored on disk during the system library build procedures of system generation. Both the system and users execute these programs to perform system housekeeping and common utility functions. (Indeed, they are sometimes referred to as *CUSPs*, commonly used system programs.) The system manager can use the programs to monitor and regulate system usage. Some library programs can be tailored by altering the source statements supplied by Digital and recompiling to replace the current copy on the system disk.

Software Options are Chosen During System Generation.

System generation is normally a one-time operation in which the system manager defines the hardware configuration and selects the basic software options. The system manager needs to perform a system generation only when the system is first installed or when the hardware configuration changes. Software options can be included in the system to tailor the system to the needs of the application.

In addition to defining the number and kinds of peripherals and processing hardware during system generation, the system manager defines special configuration options. Some of these options are discussed below.

Pseudo Keyboards

The system manager can define the system to have one or more pseudo keyboards. Using a pseudo keyboard as a communications device, you can write a program to control other jobs. In addition, each copy of the BATCH system program requires one pseudo keyboard to run jobs in a batch stream.

Multiple Terminal Service

The multiple terminal service option allows one program to interact with several users simultaneously by servicing their terminals on one I/O channel. This eliminates the need to run separate copies of the same program when several terminals must perform a similar function.

Floating Point Precision and Scaled Arithmetic

The system manager can select either single precision (2-word) or double precision (4-word) floating point numeric format. If the system has floating point hardware, the system manager can select a floating point math package that will increase processing speed by using the hardware instructions. The scaled arithmetic feature is included in all 4-word floating point math packages. Scaled arithmetic avoids loss of precision in floating point calculations; it is therefore very useful in calculating sums of money that cannot be manipulated easily as integer quantities.

System-Wide Logical Names

RSTS/E allows the system manager to assign up to 50 logical names on a system-wide basis. Any user can type a system-wide logical name to access the device (and, optionally, the account) it represents.

File Processor Buffering

The optional file processor (FIP) buffering module accelerates file processing on the RSTS/E system. The module reduces the number of accesses to disk by maintaining more than one disk directory block in memory. The system manager can enhance FIP buffering by allocating additional memory to extended buffer space for use as a cache for disk directory blocks.

RSTS/E Supports Software Disk Caching of File Directories and Data Blocks.

Software disk cache is a dynamically allocated portion of main memory in which blocks of disk-accessed file data are stored. When a request is made to read a disk block, the operating system first checks the cache. If the block of data is there, a physical disk access is avoided. This results in faster program execution because disk accesses are minimized.

When the cache is full, new information is read into an area that contains the least recently used block of data. This automatic mechanism ensures that frequently-used blocks of data remain in the cache.

Cache size is determined by the system manager. The system manager can designate specific files for caching, or can specify that all files be cached. The system manager can also enable or disable caching of file data, independent of caching disk directory blocks. This system-level capability gives the system manager a powerful method of tuning system performance.

RSTS/E Has System Utility Programs for Both the System Manager and General User.

Some system management utilities are privileged programs and can be run only by the system manager or privileged users. Other utilities are not privileged and can be run by the general user, but have privileged features that can be executed only by the system manager.

System management utilities include: system initialization and maintenance programs, resource management and accounting programs, system error logging and analysis programs, operator services and spooling programs, and user communication programs.

Systems Initialization

After generating the system, the system manager bootstraps the RSTS/E system to load the initialization (INIT) code into memory. The INIT code is a collection of routines used to create the file structures, system files, and start-up conditions required for normal operation of the RSTS/E system. The INIT code is essentially one large stand alone program with many functions. INIT includes routines which ensure the integrity of disk file structures and perform many checks on the hardware configuration. Options are provided which enable the system to function even when certain hardware elements are inoperative. Finally, the initialization code is responsible for loading the RSTS/E Monitor into memory for normal timesharing operations.

Once the default system initialization start-up parameters are set up, the system manager does not have to repeat manual start-up each time the system is started. Using the automatic restart feature, the RSTS/E system can recover and restart the timesharing session automatically after a system malfunction or power failure. When the system is started in automatic restart mode, control by-passes all parts of the start-up code that call for operator intervention.

System Accounts and Libraries

RSTS/E systems have three system accounts that are integral to the operation of the system and have auxiliary accounts for more efficient operation of the system. The Master File Directory (MFD) account is used on the system device and other disk devices in the system to control system access. The system library account is used by the RSTS/E system to manage a library of generally available and restricted use system programs and message and control files. A third special system account contains RSTS/E monitor files and routines which are critical to the operation of the system.

Of particular interest to the system manager is the accounting information maintained on each user account in the MFD on the system device. This accounting information is normally accessed through the system accounting utility programs. The system manager or privileged users can also access and change this information for programmers using the SYS monitor functions.

Privileged Capabilities and System Operation

Privilege is a special condition for a user job. With privilege, a job has capabilities not available to other, nonprivileged jobs. These capabilities are:

- Unlimited access on the system
- Ability to designate privileged programs
- Use of privileged aspects of system programs
- Use of privileged SYS system functions and the PEEK function

A job has privilege under one of the following conditions:

- It is a logged-out job (a job without an account)
- It is running under a privileged account
- It is running a privileged program

A logged-out job has privilege because the system must perform certain privileged operations to log a job in to the system. The privilege remains in effect as long as the job remains logged out.

A job running under a privileged account has privilege, and the privilege remains in effect until it is logged out or changes to a nonprivileged account.

A privileged program is an executable file with a protection code of <192> (the sum of the privileged protection <128> and the compiled file protection <64>) or greater. The privilege is temporary unless the job is running under an account which itself has permanent privilege. The privilege remains until the program exits or until the program drops its temporary privilege. This temporary privilege allows a nonprivileged user to run a privileged program.

The following paragraphs summarize briefly privileged capabilities.

Unlimited Access

No file in the RSTS/E system can be protected against a privileged job. A privileged job can create and delete files under any account number on any disk. Such unlimited access does not generate the normal PROTECTION VIOLATION error.

Ability to Designate Privileged Programs

A program is privileged when it is an executable file and has a protection code of <192> or greater. Only the system manager or other users running under privileged accounts can create or modify privileged programs.

Use of Privileged Features of System Programs

If a program is designated privileged and is not protected against execution, any user can run the program with temporary privilege. Temporary privilege means that system operations normally reserved to a user of a privileged account can be executed while running under nonprivileged account.

The ability to designate a program as privileged allows the system manager to extend use of privileged functions to nonprivileged users. For example, the program TTYSET allows general users to change characteristics of their terminals. Such an action is a privileged system function; with temporary privilege, however, execution of the function by the owner of a nonprivileged account does not generate the normal PROTECTION VIOLATION error.

The same TTYSET program additionally allows a privileged user to change characteristics of other terminals. A check is built into the program to ensure that a user attempting to change the characteristics of a terminal other than his own is indeed a permanently privileged user. In effect, the execution of some privileged functions is made available to the nonprivileged user but other privileged features are available only to those users logged into the system under privileged accounts.

General System Utility Programs

RSTS/E provides several utility programs available to the general user. These programs include system information and terminal utility programs, file utility programs, and special service programs. Like the system management utilities, they are stored in the system library account and are called and executed by issuing the RUN system command or, if it is available, the appropriate CCL command.

The list of programs that follows is not exhaustive; it is only meant to suggest the range of utilities available under RSTS/E operating systems.

System Information Programs

SYSTAT	Provides current status of system jobs, devices, and buffers. Identifies active jobs in the system, accounts under which they are running, their size, their associated keyboard (if attached), and their current activity. Also identifies which devices are assigned and to which jobs.
QUOLST	Provides current system information, including number of free blocks remaining on the system structure, number of blocks used by an account, number of free blocks remaining in and disk quota of an account.
MONEY	Prints current account status, including amount of CPU time, connect time, kilo-core ticks and disk blocks used.
GRIPE	Allows the user to communicate with the system manager.
TTYSET	Allows a user to establish terminal characteristics. The user can call a macro command that establishes the standard characteristics for a selected type of terminal or can select an individual combination of characteristics.

INUSE	Prints the message "IN USE" at a terminal to allow a user to leave the terminal momentarily.
PIP	Allows the user to transfer files from one device to another, merge files, delete files, initialize a device directory or list a device directory.
COPY	Copies all the information on a disk, DECtape or magnetic tape device.
BACKUP	A package of programs which allow the user to preserve and recall files stored under one or more user accounts by transferring multiple files from the private or public disk structure to a private disk, DECtape, or magnetic tape.
DIRECT	Prints directories of selected file-structured devices.
FILCOM	Compares two text files line by line and prints any differences found.

Special Service Programs

MAC MACRO	Assemble MACRO-11 source code into object format. MAC operates under the RSX-11 run-time system; MACRO operates under the RT-11 run-time system.
LINK	Link object modules produced by FORTRAN or MACRO into an executable image which runs under the RT-11 run-time system.
TKB (Task Builder)	Builds an executable image by linking object modules produced by the MAC assembler or language processors other than FORTRAN. The resulting task image runs under the RSX run-time system specified by the user.
QUE	Creates jobs that are to be executed by spooling programs such as BATCH and SPOOL. It also lists pending requests and kills pending requests.
RUNOFF	Generates a formatted listing of a text file containing special RUNOFF text formating commands.

Batch Processing Lets You Submit Jobs Without Using Terminal Dialog.

BATCH is particularly useful in executing large data processing operations for which interactive requirements are not a factor. Batch input can be submitted from standard job control files on a random access file-structured device or from an I/O device. The input consists of elements of the batch control language and is collectively referred to as a *batch stream*. It is possible to execute multiple streams simultaneously by running multiple copies of the BATCH program. The capability to run more than a single batch stream is controlled by the system manager.

Logical Disk Structures Let You Access System and User Data as well as Executable Code.

Logical disk structure is divided into two types: public and private. The file structure on a disk, whether public or private, is the same. On a public disk, any user can create files. Every user has an account on a public disk. There is always at least one public disk on the system, which is called the "system disk." All public disks together on a system are called the "public structure" because the system itself treats all the public disks together as a unit. For example, when a program creates a file in the public structure, that file is placed on the public disk with the most space available. This is done to ensure proper distribution of files across the disks in the public structure.

The system disk contains the system code. Language processors and the library of system programs are also contained on the public structure. Storage of active user jobs which are temporarily swapped out of memory are in swapping files, at least one of which is on the system disk.

Any remaining disk drives in the RSTS/E disk structure can be devoted to private disk packs or disk cartridges. A private disk is one that belongs to a few user accounts, conceivably to a single user account. Files can be created only under these accounts, and can be read (or written) by other users only if the protection code of the file permits. A user who does not have an account on a private disk cannot create a file on it.

You Have a Choice of Three File Access Methods.

The file access methods available for the RSTS/E system include:

- RMS-11
- BASIC-PLUS
- DMS-500

RMS-11

RMS-11 is the main file and record access method available on RSTS/E. It is used by BASIC-PLUS-2, COBOL-81, FORTRAN-77, and optionally on MACRO-11 and DIBOL-11. In addition, most of the utility programs and layered software products, e.g. SORT-11 and DATATRIEVE-11, will only work when using files maintained through RMS-11.

RMS-11 supports three file organizations:

- Sequential
- Relative
- Indexed

The indexed file organization allows each indexed file to have one primary key and up to 254 alternative keys. In addition to random access based on key values, pro-

grams can access records in an indexed file sequentially in ascending order by key values. Records are stored physically only in primary key order.

RMS-11 supports four record formats:

- Fixed length records
- Variable length records
- Variable length with fixed control fields
- Stream records

Indexed files are restricted to either of the two record formats: fixed or variable. The stream record format is restricted to sequential disk files only. Languages that do not use RMS (e.g. FORTRAN IV) cannot process RMS files unless the record format is stream.

User programs are provided with logical data record access to RMS files through extended language syntax statements. The form of the statements is dependent upon the application language interface. The functions provided are:

- OPEN
- CLOSE
- READ/GET
- WRITE/PUT
- REWRITE/UPDATE
- DELETE

In addition to the facilities provided for programming languages, there is a set of RMS-11 utilities that enable the user to create, load, maintain, and backup RMS-11 files.

BASIC-PLUS

BASIC-PLUS on RSTS/E provides three methods of file access:

Formatted ASCII	For standard sequential I/O operations.
Virtual Arrays	For random access of large data files. A virtual array is stored on disk and can contain string, integer and floating point matrices.
Record I/O	Allows the user to have complete control over I/O operations.

Formatted ASCII data files are the simplest method of data storage, involving a logical extension of the BASIC-PLUS PRINT and INPUT statements. The INPUT statement allows data to be entered to a running program from an external device, for example, the user's keyboard, a disk, DECtape, or paper tape reader. The PRINT statement causes the output of a specified string of characters to a selected device.

The PRINT-USING statement allows the user to control output formatting. A special set of formatting characters allows the user to format strings and numeric

fields with tabs, special characters and punctuation. For example, the user can format check amounts with asterisk-fill for protection.

The RSTS/E virtual array facility provides the means for a program to operate on data structures that require fast random access processing yet are too large to be accommodated in memory at one time. To accomplish this, RSTS/E uses the disk file system for storage of data arrays, and maintains only portions of these files in memory at any given time.

Virtual arrays are stored as unformatted binary data. This means that no I/O conversions (internal form to ASCII) need to be performed in storing or retrieving elements in virtual storage. Thus, there is no loss of precision in these arrays, and no time wasted performing conversions.

The third type of I/O, record I/O, permits a program to have complete control of I/O operations. Record I/O is a flexible and efficient technique of data transfer. Input and output to record I/O file is performed by the BASIC-PLUS GET and PUT statements. These statements allow the user to read or write specific blocks (physical records) of a file, where the block size is dependent on the type of device being accessed. For example, disk file blocks are always 512 bytes long, while records from a keyboard device are one line long, where a line is delimited by a carriage return or similar terminating character. With disk files, the program has the capability of performing random access I/O to any block of the file. Furthermore, using record I/O operations, the user can create a logical organization for file formats by controlling record length.

DMS-500

DMS-500 is a collection of BASIC-PLUS routines which are optional on RSTS/E systems. DMS-500 comprises a selection of routines which provide capabilities for organizing and processing data records stored in indexed, indexed sequential, and relative file structures. The optional DIBOL-11/DECFORM language package can use either RMS-11 or DMS-500.

The major components of DMS-500 include:

- ISAM/RAM (Indexed Sequential/Relative Access Method). Random access is either by means of a unique or duplicate ASCII key or by means of a relative record number.
- IAM (Indexed Access Method). A hashing technique is used to randomly store or retrieve a data record with a minimum number of disk accesses.
- DSORT (Extended Disk Sort) This method sorts disk resident multivolume files containing blocked, fixed-length records up to 512 bytes in length on up to 15 ascending key fields.

In addition to the basic RSTS/E file handling capabilities, DMS-500 IASM/RAM provides multi-volume disk file support by logically linking together multiple files.

System Function Calls Bypass the Runtime System.

Many programs, particularly MACRO-11 assembly language programs, are required to perform functions which directly affect the way in which the system handles such things as memory, I/O devices, run-time systems, etc. Rather than allow the application or system programmer to perform these manipulations in an uncontrolled way, the RSTS/E system provides a series of System Function Calls. These are calls from the program directly to the monitor that bypass the runtime system. The monitor performs the function, then returns to the calling program.

Some of the system function calls are privileged and can be issued only by privileged users or jobs while others are available to all users. This ensures that the unprivileged user cannot gain access to system functions which could drastically change the way the system is supposed to operate.

System function calls are available to most of the high level languages available on RSTS/E. The calls are formatted for each language consistent with the general language syntax. One major note is that the calls are very system dependent.

The *Peek* system call is a privileged system call that allows any privileged job to examine any location in the monitor part of memory. This allows the user to read the monitor code, monitor data structures, including data structures of other users, and the file processor. This function does not allow a user program to examine the contents of another user's program.

Micro/RSTS is an Execute-Only System Designed Especially for the MICRO/PDP-11.

Micro/RSTS, a compact subset of RSTS/E, is an application-only time-sharing system capable of running, but not developing, programs. It runs exclusively on the MICRO/PDP-11 and typically serves one to four users in a small business or department.

Micro/RSTS disk requirements are small—about 2.5 Mbytes versus 10 Mbytes for RSTS/E. Programs for Micro/RSTS are coded, compiled, linked, and debugged on the full RSTS/E system and then loaded into the smaller MICRO/PDP-11 system for execution. Applications can be developed on one RSTS/E system for use on several scattered Micro/RSTS systems.

Micro/RSTS is a pregenerated system that the customer can install with an interactive installation procedure. The lack of SYSGEN requirements contributes to its low system management overhead.

- A maximum of nine user jobs can run on Micro/RSTS at one time, although multiple-terminal service allows up to 12 terminals.
- Any terminal can be connected to the system remotely through an appropriate modem.

- Directory caching allows the saving of file device directories in main memory for quick access.
- If the error handling code can't recover from an error, the read/write area of memory is dumped into a file named CRASH.SYS on the system disk.
- Echo mode for terminal I/O allows typed characters to be taken away from the current cursor position and echoed elsewhere on the screen.
- Up to 50 system-wide logical names can be given to devices.
- Shareable resident libraries of routines or data can be included on the system disk and clustered to save memory.
- The FMS Forms Management System is supported.

Runtime Systems

Micro/RSTS includes three runtime systems. The *DCL* (Digital Command Language) runtime system's keyboard monitor is the default interface between the user and Micro/RSTS. It recognizes a subset of the RSTS/E DCL commands. The *RSX* runtime system provides a versatile programming environment compatible with the VAX/VMS operating system. The *RT-11* runtime system (with its limited range of languages) is best suited to run existing RT-11 programs, rather than to develop new ones.

Micro/RSTS Utilities

Micro/RSTS supplies many RSTS/E utilities, including:

SORT — sorts a selected key field in each record of a file in either ASCII or EBCDIC collating sequence.

EDT — the standard text editor. EDT allows users to recover editing work performed prior to a system crash.

UTILITY — supplies a variety of useful functions, such as:

- Add/remove system files
- Add/remove logical names
- Broadcast messages to terminals
- Change passwords of accounts
- Detach or kill jobs

BACKUP — backs up disk data by copying selected files to other media.

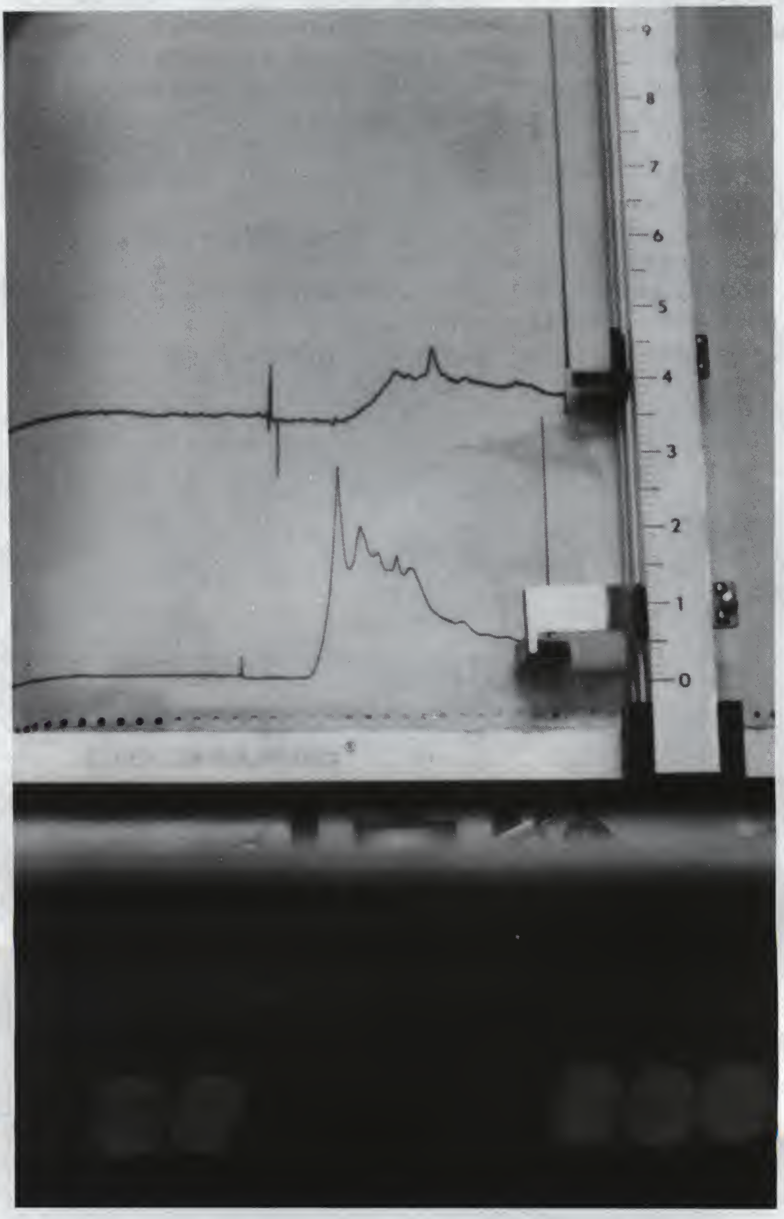
ANALYS — aids analysis of system crashes.

ERRCPY — displays the hardware error log.

Application Development Kit

The Micro/RSTS Application Development Kit provides software and documentation in support of native MACRO-11 assembly-level language and high-level language program development. The Application Development Kit includes:

- MACRO-11 programming — with an assembler, a FILE DUMP utility, a Resource Monitor Display (RMD), an On-line Debugging Technique (ODT), and MACRO libraries.
- System programming tools — with the necessary RSX components to develop privileged software such as user-written device drivers. It also includes tools such as a loadable executive debugger and loadable crash dump drivers to assist programmers in developing privileged code.
- RMS (Records Management System) backup and restore utilities.


9
8
7
6
5
4
3
2
1
0

Chapter 5

RT-11

RT-11 Offers Realtime Versatility and a User-Friendly Environment.

Digital provides a compact operating system for realtime, single-user applications: RT-11. It is well suited to such applications as laboratory and factory instrument control, manufacturing process control, flight management, mapping problems, and numerous other technical jobs. RT-11 also finds widespread use in commercial applications, and RT-11 systems can be found doing word processing, medical record management, computerized estimating for general contractors, and typesetting for newspaper publications.

But despite its small size, RT-11 is far from primitive in either its services or its friendly environment. For example, RT-11 supports the standard Digital Command Language (DCL), making access to system services as easy as typing English-like commands. Instead of having to manage system calls directly, you can call services through DCL commands that will prompt for any missing parameters, and will offer help if a problem or question arises.

The keypad editor, KED, is especially designed for a wide range of video terminals, and takes advantage of all their advanced features. Screen-oriented editing lets you see immediately what effect your editing instructions have, and makes quick changes to correct errors or to accommodate altered program needs. KED is simple to use and easy to learn; even a novice can begin editing right away, since most common editing requirements use no more than two keystrokes, and the editing instructions themselves are clearly named to explain what they do.

Other software features are described later in this chapter to show you the full range of tasks RT-11 accomplishes in making the system accessible to both novice and experienced users alike.

RT-11 Offers a Choice of Monitors.

The monitor is that part of the operating system that controls and allocates the services of the rest of the system. RT-11 systems give you a choice of any one of three different monitors. To accommodate the range of typical RT-11 users, Digital supplies the system with a single job monitor, a foreground/background monitor, and an extended memory monitor.

A *single-job monitor*, called SJ, organizes the system for single-user, single-program conditions. SJ can run in configurations with as little as 24 Kbytes of memory and still not sacrifice access to system programs, services, or features (except extended memory and the use of a foreground or system job). Since the resident portion of the SJ monitor itself needs only four Kbytes of memory, it leaves lots of room for extensive program development. Also, because the monitor services interrupts very quickly, SJ systems are ideal for programs that require a high data transfer rate.

A *foreground/background* monitor, called FB, takes advantage of the fact that much central processor time is often spent waiting for external events such as I/O transfer or realtime interrupts. In FB monitor systems this waiting time is put to good use by letting you use the central processor for another (background) job while your principal job is pausing. For example, if your foreground monitor is running a laboratory sampling program, your background job could be a FORTRAN program development session, or an accounting file update. When the foreground pauses to receive data from the instruments, the background lets a programmer work on coding or updating the file.

In FB situations, the foreground job is always of higher priority than the background one, so that the system returns control to the foreground job when it is again ready to run. The FB monitor can set timer routines and send data and messages between the two jobs.

Finally, there is an extended memory monitor, or XM. It allows both foreground and background jobs to extend their effective logical program space beyond the 64 Kbyte space imposed by 16-bit addresses on PDP-11 computers. The XM monitor contains all the features of FB plus the capability of accessing up to four Mbytes of memory. Extended memory is managed by the monitor as a system resource, and dynamically allocated to programs as they need it. The extended memory overlay feature permits overlays to reside in extended memory rather than on disk; this results in faster execution time for overlaid programs.

These three monitors are upwardly compatible: FB provides all the services of SJ; XM provides all the services of FB. As system generation options, FB and XM monitors support error logging and system jobs.

You can access the monitor through either keyboard commands or programmed requests. With keyboard commands, you can load and run programs, start or restart programs at specific addresses, modify the contents of memory, and assign alternative device names, to mention only a few of the services available. If you have a series of keyboard commands you may create an *indirect command file*, a list of commands to be executed sequentially by the computer. Typically, you would write an indirect file for jobs that use a lot of computer time but do not need your supervision or intervention. Another possible use of indirect files is for command sequences that you use repeatedly, and which are time-consuming to retype. Simply construct the indirect file and call it up when you want the monitor command procedures it includes.

Programmed requests to the monitor appear in a MACRO-11 source library and permit an assembly language program to access monitor services. Once a program is running, it communicates to the monitor through programmed requests. If your programs are written in FORTRAN IV, they can access the monitor services through the system subroutine library. Typical programmed requests manipulate files, perform input and output, and suspend or resume program operations.

System Utilities Offer File Transfer, Backup, and Protection.

Though you may call most of the system services through keyboard monitor commands, the keyboard monitor itself does not perform the work. Instead, it passes the requests on to the appropriate system utility programs. By providing this simple interface, the monitor reduces the complexity of programming or operating the computer, and thus increases your productivity. Some of the utility programs and their functions are listed below.

Peripheral Interchange Program

The Peripheral Interchange Program (PIP) is for file transfer and file maintenance utilities. PIP is used to transfer files between any of the RT-11 devices and to merge, rename, and delete files. With PIP you can perform numerous operations simply and avoid the difficulty usually associated with file transfer and manipulation requirements.

PIP allows you to protect files against accidental deletion. File protection is indicated by the letter "P" next to the file size as listed in the file's directory. Files may be protected and unprotected only by using the RENAME keyboard command or the PIP utility.

Backup Utility Program

This utility program provides a quick way to store a large volume or file on a set of several smaller volumes even if the file is larger than one of the smaller volumes. The Backup Utility Program (BUP) lets you initialize backup volumes, obtain directory information about a set of backup volumes, and RESTORE a volume on file from a set of backup volumes to its original form as either a file on a volume or as an entire volume. Unlike PIP, BUP does not produce RT-11 structured files when backing up and therefore the information on the backup volumes cannot be accessed as such by other RT-11 utilities. The RESTORE facility of BUP recreates the RT-11 file structure. This very fast, multivolume backup/restore facility supports the streaming capabilities of Digital's nine-track 1600 bpi tape drives, the TSV05 and TU80.

Device Utility Program

The Device Utility Program (DUP) is for device maintenance. DUP creates files on file-structured RT-11 devices. It can also extend files on certain file-structured

devices (disks and DECtape), and it can compress, scan for bad blocks, image copy, initialize, or boot RT-11 file-structured devices.

Directory Program

The Directory Program (DIR) performs a wide range of directory listing operations. It can list directory information about a specific device, such as the number of files stored on the device, their names, and their creation dates. DIR can list details about certain files, too, including their names, file types, and sizes in blocks. DIR can also print a device directory summary, and it can organize its listings in several ways, such as alphabetically or chronologically.

Command String Interpreter

The Command String Interpreter (CSI) is the part of the RT-11 system that accepts a line of ASCII input, usually from the user at the console terminal, and interprets it as a string of input specifications, output specifications, and options for use by a system utility program.

Librarian

The Librarian Utility Program (LIBR) lets you create, update, modify, list, and maintain library files. A library file is a direct access file (a file that has a directory) that contains one or more modules of the same module type. The librarian organizes the library files so that the linker and MACRO assembler can access them rapidly. The modules in a library file can be routines that are repeatedly used in a program, routines that are used by more than one program, or routines that are related and simply gathered together for convenience.

DUMP

DUMP is the RT-11 program that prints on the console or lineprinter, or writes to a file, all or any part of a file in octal words, octal bytes, ASCII characters, or Radix-50 characters. DUMP is particularly useful for examining directories and files that contain binary data.

File Exchange Program

The File Exchange Program (FILEX) is a general file transfer program that converts files from one format to another so that they can be used with other operating systems.

Source Compare Program

The Source Compare Program (SRCCOM) compares two ASCII files and lists the differences between them. SRCCOM can either print the results or store them in a file. SRCCOM is particularly useful when it is necessary to compare two similar versions of a source program. A file comparison listing highlights the changes made to a program during an editing session. SRCCOM can also produce (as output) a file of SLP commands that can be used later with SLP to patch an original file to match its edited version.

Binary Compare Program

The Binary Compare Program (BINCOM) compares two binary files and lists the differences between them. You can direct BINCOM to print the results of the comparison at the terminal or lineprinter, or store them in a file. It can also create an indirect command file that invokes SIPP to patch one save file to match another version.

Resource Program

The Resource Program (RESORC) displays information about the system configuration.

Linker

The RT-11 Linker (LINK) converts object modules produced by an RT-11 supported language processor into a format suitable for loading and execution. The linker processes the object modules of the main program and subroutines to:

- Relocate each object module and assign absolute addresses
- Link the modules by correlating global symbols that are defined in one module and referenced in another
- Create the initial control block for the linked program that the GET, R, RUN, and FRUN commands use
- Create an overlay structure if specified and include the necessary run-time overlay handler and tables
- Search libraries specified by the user, to locate any unresolved globals
- Automatically search a default system library to locate any remaining unresolved globals
- Produce a map showing the layout of the executable module
- Produce a symbol definition file

The linker runs in a minimal RT-11 system of 24 Kbytes of memory; it uses any additional memory to facilitate efficient linking and to extend the size of the symbol table. The linker accepts input from any random access device on the system; there must be at least one random-access device (disk or DECtape) for memory image or relocatable format output.

RT-11 Offers Four Ways to Change or Debug Your Programs.

Four RT-11 programs help you debug programs and make changes to programs that are already assembled. They are: the On-line Debugging Technique (ODT), Save Image Patch Program (SIPP), the Object Module Patching Utility (PAT), and the Source Language Patch Program (SLP).

RT-11 On-Line Debugging Technique

RT-11 On-line Debugging Technique (ODT) is a program supplied with the system that aids in debugging assembly language programs. From the terminal, you can direct the execution of programs with ODT. ODT performs the following tasks:

- Prints the contents of any location for examination or alteration
- Runs all or any portion of an object program using the breakpoint feature
- Searches the object program for specific bit patterns
- Searches the object program for words that reference a specific word
- Calculates offsets for relative addresses
- Fills a single word, block of words, byte or block of bytes with a designated value

Save Image Patch Program

The save image patch program (SIPP) lets you make modifications to any RT-11 file that exists on a random-access storage volume. It is especially useful for maintaining .SAV image files. Using SIPP, you can examine locations within a file. You can use SIPP from the console, an indirect command file or a BATCH stream to patch all files created with the linker. SIPP can patch overlaid files created with the Version 4 linker, and nonoverlaid files created by previous linkers.

SIPP was designed to replace the former PATCH utility. However, PATCH is included in the Version 4 release so that patches that have been published prior to this release can be installed, and PATCH can patch overlaid files created with the earlier linker.

Object Module Patch Utility

The RT-11 object module patch utility (PAT) allows you to patch or update any code in a relocatable binary object module. PAT does not permit examination of the octal contents of an object module; that is a function of SIPP. An advantage to using PAT is that relatively large patches can be added to an object module without performing any octal calculation. PAT accepts a file containing corrections or additional instructions and applies these corrections and additions to the original object module.

Source Language Patch Program

SLP is a patching tool you can use for modifying source files. When used with SRCCOM, you can patch a source file so that it will match an edited version. SLP accepts as input a source file you wish to patch and a command file created by SRCCOM.

RT-11 Offers a Choice of Text Editors.

One of the most useful of all utilities is a text editor, since it makes the job of creating, correcting, and updating programs and files a simple matter of using commands at the terminal. RT-11 provides a selection of editors, including EDIT and KED.

EDIT is a program that creates or modifies ASCII source files and prepares them as input to other programs, such as compilers or assemblers. The EDIT program can read files from any input device and write them on any output device. It is a line-oriented editor, most useful for hard copy terminals.

EDIT performs the four functions that are exactly those you would expect an editing program to provide:

- Locates the text to be changed
- Executes and verifies the changes you command
- Lists a copy of the edited page on your terminal
- Outputs the page to the output file

In order to process text, EDIT thinks of a file as divided into logical units called pages of about 50 or 60 lines in length. Such a logical page corresponds roughly to a physical page in a program listing. One page at a time is read from the input file to the buffers, where it becomes available for editing.

KED is a video display editor meant for use with VT100 and VT100-compatible terminals. It takes advantage of the special keypad to the right of the terminal's keyboard. Keypad keys provide quick operation of various editing functions, such as moving the cursor left or right by a word or character. KED provides a HELP file in order to make keypad editing easy to learn and enjoyable to use.

BATCH Lets RT-11 Run Unattended.

RT-11 BATCH is a complete job control language that is ideally suited to frequently run production jobs, large and long-running programs, and programs that require little or no interaction with the user.

RT-11 BATCH permits you to:

- Execute an RT-11 BATCH stream from any legal RT-11 input device
- Output a log file to any legal RT-11 output device (except magtape or cassette)
- Execute the BATCH stream with the single-job monitor or in the background of the foreground/background (FB) monitor or with the extended memory monitor
- Generate and support system-independent BATCH language jobs
- Execute RT-11 monitor commands from the BATCH stream

An improvement over BATCH is the Indirect Control File Processor(IND), which executes indirect control files to define symbols, execute keyboard monitor commands, access files, pass parameters, and perform logical tests. IND is compatible with the RSX-11 control file processor, and with few or no changes a command file written for either RT-11 or RSX-11 will execute under the other operating system.

Additional Software Components Make Your Job Easier.

The RT-11 operating system supplies several other useful software components that help in the smooth operation of your computer. Three features available under RT-11 are the *System Jobs Feature*, the *Queue Package*, and the *Error Logger*.

The System Jobs Feature permits an FB or XM monitor created through system generation to run up to six extra jobs, in addition to the normal foreground and background jobs. Digital provides two system jobs: the file queuing job, QUEUE, and the error logger, EL. If you generate a monitor with support for system jobs, you can run either or both of the supplied system jobs along with a foreground and background job (although this reduces memory available for foreground and background operation). Under the distributed FB monitor, you can run a system job as the foreground job.

With the file queuing package (QUEUE and QUEMAN), you can send files to any valid RT-11 output device. Although the Queue Package is particularly useful for obtaining hardcopy listings of files, queuing is not restricted to a lineprinter or to other serial devices. The QUEUE program runs with the FB or XM monitors, as either a foreground or system job. QUEMAN, the user interface to QUEUE, runs in the background.

The Error Logger (EL) monitors the hardware reliability of the system. It keeps a statistical record of all I/O operations on devices that call it. At intervals that you determine, the error logger produces individual or summary reports on some or all of the errors that have occurred. Support for the error logger must be obtained through system generation. The error logger runs with the FB or XM monitors, as either a foreground or system job, but is not supported under the SJ monitor.

Single-Line Editor (SL)

This feature lets you edit the current keyboard command line or CSI command string typed on a video terminal prior to terminating the line. The previous command or input line can also be recalled for editing.

Logical Disk Subsetting (LD)

This facility lets you define logical disks, which are subsets of physical disks. Operations can then be performed as though the logical disk was a physical disk. This feature provides for more directory entry space and enhances device and file operation performance.

Virtual Memory (VM) Handler

RT-11 supports memory above 56 Kbytes (and up to four Mbytes on Q-bus systems) as if it were an RT-11 file structured random access device. The VM Handler can be used as the systems device or a data device under the SJ and FB monitors, while under the XM monitor it can be a data device only.

System Jobs

Both the FB and XM monitors can optionally support up to six extra jobs, called system jobs. These system jobs are programs supplied by Digital and run in parallel with user-written foreground and background jobs. System job support is included in the distributed XM monitor and is also available under the FB monitor through system generation.

".FETCHable" Handlers Under XM

A SYSGEN option allows handlers to be dynamically loaded and released by user programs under the XM monitor. Previously, all handlers needed by user jobs had to be permanently resident in memory, even if they were not being used. Background user programs may now issue the .FETCH and .RELEAS requests to load handlers into memory for use and release when finished, thereby freeing valuable low memory space for other uses.

Write Protect for Diskettes

Users can use the "diskette-write-protect" feature via a SET command to the handlers.

The System Subroutine Library Lets You Access the Monitors.

The RT-11 FORTRAN IV System Subroutine Library (SYSLIB) is a collection of FORTRAN-callable routines that allows a FORTRAN user to access various features of RT-11 foreground/background (FB) and single-job (SJ) monitors. SYSLIB also provides various utility functions, a complete character string manipulation package, and two-word integer support. This library file is the default library that the linker uses to resolve undefined globals and is resident on the system device (SY:).

Some of the functions provided by SYSLIB are:

- Complete RT-11 I/O facilities, including synchronous, asynchronous, and completion-driven modes of operation. FORTRAN subroutines may be activated upon completion of an input/output operation.
- Timed scheduling of asynchronous sub jobs (completion routines). This feature is standard on FB and optional on the SJ monitor.
- Complete facilities for interjob communication between foreground and background jobs (FB and XM only).
- FORTRAN interrupt service routines.
- Complete timer support facilities, including timed suspension and time-of-day information. These timer facilities support either 50- or 60-cycle clocks.
- All auxiliary input/output functions provided by RT-11, including the capabilities of opening, closing, renaming, creating, and deleting files from any device.
- All monitor-level informational functions, such as job partition parameters, device statistics, and input/output channel statistics.

- Access to the RT-11 Command String Interpreter (CSI) for acceptance and parsing of standard RT-11 command strings.
- A character string manipulation package supporting variable-length character strings.
- INTEGER*4 support routines that allow two-word integer computations.

SYSLIB allows a FORTRAN IV user to write almost all application programs completely in FORTRAN IV with no assembly language coding.

RTEM-11 Lets Programs Developed on RSX-11 and VAX/VMS Run On RT-11.

The RTEM-11 emulator is an option on RSX-11M-PLUS, RSX-11M, and VAX/VMS that provides an RT-11 program-developement environment on those systems. Several users can develop RT-11 applications concurrently on an RSX-11 or VAX/VMS host system. Users can create, edit, assemble, and link programs using RTEM-11 and then execute these programs on an appropriately configured RT-11 system. Programs developed on RTEM-11 execute the same way as if they had been developed on RT-11.

Most programs developed on RTEM-11 can also be debugged and tested on that system, although the execution environment supplied is foreground/background only. Examples of software that can be built, but not debugged or executed on RTEM-11, are programs that access the I/O page and any program that requires the XM monitor.

Utilities for RTEM-11 include:

- A *File Interchange Program*, (FIP), which lets the RTEM-11 user transfer between RT-11 volumes and host volumes.
- An *Indirect Control File Processor*,(IND),which processes files containing streams in a manner similar to the RSX-11M utility.
- A Jack of All Trades, (JOAT), which performs system and device operations. For example, while most program developement can be done using just the system device, console terminal, and line printer, other peripheral devices may be required. JOAT permits access to any host device supported by RTEM-11. JOAT can also be used to terminate RTEM-11, pass command lines to the host, and show current device usage.

Monitor and Command Language Commands

The primary system/user interface is provided in PDP-11 operating systems by either monitor software or special command language interface programs that run under the monitor. The monitor software and command languages allow the user to request the system to set system parameters, load and run programs, and control program execution.

An input command line consists of the command name (an English word that describes the operation to be performed) followed by a space and a command argument. The command to run a program is the word RUN followed by the name of the file containing the program, for example. If the command name is long, it can usually be abbreviated.

In the RT-11 system, a monitor component called the keyboard monitor performs the function of notifying the user that the monitor is ready for input by printing a period at the left margin. The user enters a command string on the same line and terminates the command string by typing the carriage return key.

In the RSTS/E system, there are four keyboard monitors that share the responsibility for interpreting commands: DCL, BASIC-PLUS, RSX, and RT-11. All of these interpret sets of system commands, that is, words followed by optional command parameters. These system commands allow users to perform all the fundamental functions required to use the RSTS/E system, such as logging on and off, and running programs.

I/O Commands

As mentioned above, users communicate their intentions to process data files by issuing I/O commands consisting of at least one file specification. Normally, the I/O commands used in a system are standard throughout that system. In addition, most PDP-11 operating systems share the same basic I/O command string format.

Three command string formats are generally available: Digital Command Language (DCL), the Concise Command Language (CCL), and the older, less convenient Command String Interpreter (CSI) formats. Under DCL and CCL, the command, input, and output file specifications and options may all be entered in a single line in response to the system prompt.

- COPY MYFIL YOURFIL

Omitted information will be prompted for by the system until the command is complete in its general format:

- COMMAND input filespec output filespec/option

Because DCL and CCL use English-like commands and options, they are easy to learn and use.

The older CSI requires several more steps: in response to the system prompt, the user enters a RUN command and the name of a program to be run, e.g., PIP (Peripheral Interchange Program). The response is a command level prompt for file specifications:

- RUN PIP
  - *   YOURFIL = MYFIL.

The general format, including single-letter switches, is:

- RUN Program
  - *   output filespec = input filespec/switch

To return to the monitor level, the user types C.

Command string switches are simply ways of appending qualifying information to an I/O command string. The switches used vary from program to program. They are not usually required in an I/O command string, since most programs assume default values for any switch.

Digital Command Language is a quick-to-learn command language that can be used by both interactive and batch-processed jobs for interactive program development, device and data file manipulation, and program execution and control.

Commands are composed of English words; command parameters such as file name specification and options can follow the command on the same line, or can be printed on subsequent lines in response to the system prompt.

In order to make DCL friendlier, Digital has supplied it with extensive facilities that both guide the user on the proper operation of the commands and supply explanations of system messages. In addition, through the use of defaults, DCL relieves users of many routine decisions and much redundant typing in order to complete parameters and options. Of course, the users can override the defaults in any command by using simple command options. Abbreviations also speed up the command typing procedure— users can type the shortest unique form of both commands and parameters. File specifications for DCL can be as simple as the name of the file only, or as detailed as a full listing of network, node device (including type, controller, and unit), directory, file name, file type, and version number.

Though there are more than a hundred DCL commands, users can also program and store commands of their own, and then use them just as the Digital-supplied commands are used.

Digital Command Language is a company standard that makes movement from one system to another easier by providing consistent formats and syntax. It is now available on RT-11, RSX-11M, RSX-11M-PLUS, RSTS/E, and VAX/VMS operating systems.

RT-11's version of the DCL is the set of keyboard monitor commands, whose features include wildcards, factoring (a simplifying method of string replacement), abbreviations, and prompts. Here is a short example of prompting:

```
COPY/C ONCATENATE
From ?
DX1: (TEST.LST, TESTA.LST)
To ?
DX2: TEST.LST.
```

The system continues to prompt for input and output file specifications until you provide them. Keyboard monitor commands can be collected together into indirect command files.

A Concise Command Language (CCL) command is used to run and pass arguments automatically to designated programs stored in the system library. The pro-

grams can be system utilities supplied with the operating system, or can be user-written console routine programs that perform application operations specific to your job.

CCL commands not only provide an easy-to-use command interface, but they can also provide protection from unauthorized use of certain programs. If a particular program performs several operations, some of which should not be available to unauthorized users, for example, the system manager can prevent those users from issuing the RUN command to run the program, but can allow them to perform the safe operation subset by using CCL commands.

In the RSX-11 systems, an additional command interface called the *Monitor Console Routine* (MCR) allows the user to perform system level operations. There are two kinds of commands that MCR accepts: general user commands and privileged user commands. General user commands provide system information, run programs, and mount and dismount devices. Privileged user commands control system operation and set system parameters.

Programmed Requests Provide Access to System Services.

All PDP-11 operating systems provide access to their numerous services through requests that programs or tasks can issue during execution. A *programmed request* inserted directly into the program provides the mechanism.

Under the RT-11 system, MACRO-11 programmers may use programmed requests to perform file manipulation, data transfer, and such other system services as loading device handlers, setting a mark time for asynchronous routines, suspending a program, and calling the Command String Interpreter (CSI).

In the RSTS/E system, users have access to the monitor's services through system function calls. The function calls allow a program to control terminal operation, to read and write core common strings, and to issue calls, in turn, to the system file processor. File processor calls, in turn, enable a program to set program run priority and privileges, scan a file specification, assign devices, set terminal characteristics, and perform directory operations. When the function operation is performed, the program continues execution.

The RSX-11 executive includes programmed services called executive directives. Directives can be executed in MACRO programs using system macro calls provided with the system. The directives allow a program to obtain system information, to control task execution, to declare signficant events, and to perform I/O operations. The RSX-11M operating system also includes programmed file control services that enable the programmer to perform record-oriented and block-oriented I/O operations.

System Utilities Perform Useful System-level Operations.

PDP-11 operating systems provide, in general, three kinds of system utility programs: program development utilities, file management utilities, and special system management utilities.

Most *system management utilities* included in an operating system are dependent on the function the operating system serves. For example, RSX-11M, RT-11, and RSTS/E include system error logging and report programs. RSTS/E and RSX-11M-PLUS include user accounting programs. The chapters on specific operating systems will give you an idea of some of the system management utilities associated with each system. For details on *file management utilities* and *program development utilities*, see the pertinent sections of this Handbook.

CTS-300 Offers Business Applications on RT-11.

CTS-300 is a complete software environment layered on top of RT-11. It uses DIBOL, a popular, friendly programming language especially designed by Digital for writing business applications.

CTS-300 provides an operating system, a higher level programming language, system utilities, a text editor, a Sort/Merge program, and program development tools. Program development may be done in a time-sharing environment. CTS-300 is capable of supporting up to 12 users or up to 16 jobs simultaneously, depending on your application programs.

Depending upon hardware and system generation options, suitably configured Datasystem computers can accommodate a mix of application and program development terminals. In addition, if the hardware includes VT100 video terminals, the DECFORM screen handler running as part of CTS-300 will take full advantage of the VT100's wide range of features.

CTS-300 has a diverse customer base of more than 15,000 banks, retail stores, insurance offices, service bureaus, wholesalers, accounting firms, and business offices of numerous companies. Some users connect their Datasystems to distributed networks, some run them as stand-alone computers.

CTS-300 provides you with immediate access to online information. Interaction with the system comes through high-speed video terminals, where all of the resources of the system are at your disposal for running programs. User programs may perform any data processing job from inventory control to accounts receivable.

Programs are not swapped in and out of memory while running, but reside in memory in dynamic partitions. This provides for two major benefits—fast terminal response time and a smaller resident operating system.

Concurrent Program Development

A major capability of CTS-300 is made available through the CRT-oriented programming editor, DKED. With this feature, it is possible to create and modify DIBOL programs on-line, with multiple copies running under Extended Memory Time-Shared DIBOL (XMTSD). Further, one or more of the developers could be remote, using dial-up lines under XMTSD.

Concurrent program development and application execution provide excellent flexibility. XMTSD runs in either the background or in the foreground. In this latter case, the background partition is available for program development.

There are two ways of using the background. The first is with one application programmer occupying the background for program development using familiar utilities. Simultaneously, XMTSD can execute applications in the foreground. The second mix occurs when more than one programmer is developing in the foreground. This is accomplished by running the editor DKED in the foreground partition, as a job under XMTSD. When a program is ready for compiling and linking, it is then submitted to a command file in the background queue. Where up to sixteen requests from various programmers are held, the requests are executed in the order submitted.

Ease of Programming

The FLAGS subroutine permits a DIBOL application to select up to eight independent options at runtime with one optional argument. During the running of an application, it is often desirable to change one of the eight options. This is accomplished by using an optional second argument to FLAGS.

In routine operator/CRT interaction, it is often desirable to time such things as messages displayed on terminals. For instance, information displayed as part of a program could take some time for an operator to read before the next application subset could occur. The SLEEP statement under TSD/XMTSD monitors will defer execution of a job for a specified period of time, thus allowing programmers to better utilize the scheduling of time among the other jobs.

The *Print Utility* provides programmers with a tool to produce simple, *ad hoc* reports from data files. This utility enables you to search a file index for report creation, while leaving the master file intact. It is unnecessary to sort the master file first, in a different order, then create a report; a small sorted index file will be sufficient. The enhanced Print Utility can improve programmer productivity.

The *ISAM Utility* allows end-user operators to create ISAM files without operator intervention. The autocreate feature can be initiated directly at a terminal or indirectly via chaining. Faster and easier file reorganization is the result.

The high-speed *Sort/Merge* utility permits users to easily define the parameters for sorting and merging data files. Users can specify up to eight key fields to control the ordering of the output records, in either an ascending or descending sequence. A wide range of control over operating parameters, such as the number of work

files to be used enables you to achieve maximum sort-efficiency. In addition, CTS-300 includes numerous utilities important in making system use easy. They are briefly explained below.

The *Linker* in CTS-300 is an easy-to-use utility that converts the output from the DIBOL compiler into a runtime format. The Linker allows a main program to be combined with many compiled external subroutines into a single executable job, and provides the ability to specify overlays. (Overlays allow the runtime job to use less main memory than would otherwise be required.)

The *Peripheral Interchange Program* (PIP) in CTS-300 allows either ASCII or binary files to be transferred among any RT-11 supported devices. It performs directory operations, renames files, extends the size of a given file, and consolidates empty files into one contiguous space. Segmented files can be merged during a PIP transfer, or multiple transfers may be executed in response to a single keyboard command.

The *File Exchange* (FILEX) program in CTS-300 provides a universal file format via floppy disks between Datasystem 300s. FILEX creates an IBM-compatible floppy in 3741 format that can be read by either IBM systems or other DEC Datasystems.

The *Device Utility Program* (DUP) in CTS-300 performs general utility functions in support of disk devices. Among DUP functions are initializing devices, scanning for bad blocks, and compressing data on a disk.

The *Directory Program* (DIR) in CTS-300 is used to list the file directories for disk devices. DIR allows directory listings to be sorted by file name, file type, date, size, or position.

The *Librarian* in CTS-300 creates and maintains libraries of commonly used programs. Each library has a catalog, listing the sections with sufficient information to enable the Linker to find them. The Librarian's tasks include creating libraries, adding new modules to existing libraries, copying options, including selective deletion and replacement during the copy, and listing the catalogs of libraries.

Command Language

CTS-300 is designed for interactive use. The keyboard commands are consistent in format and easy to understand, and the high-level command language allows transition from source code to executing code with only one statement. CTS-300 also features indirect command files, which permit you to invoke a whole stream of system commands, similar to a BATCH stream, by issuing a single, one-word command. Unlike a BATCH stream, however, there is no complicated job control language to learn. Indirect command files accept the same monitor commands that users type at the terminal.

Data Management Services

Data Management Services for CTS-300 (DMS-300) provide capabilities for handling sequential, random, or ISAM-structured files. DMS-300 also supports file sharing and multivolume files. Multivolume file support permits one file, extending over

several disk drives, to be processed sequentially or by keyed access, without requiring special programming.

Optional Software

Optional communications, business applications, and report writing packages are available for CTS-300. Among these are:

RDCP (Remote Data Communications Package)

RDCP is a powerful batch data communications package which uses both IBM 2780 and 3780 protocols. It is easy to use, yet gives the data processing center the control necessary to manage a network of systems from a single location. It can be used to communicate with IBM processors as well as other Digital Datasystems. Its key capabilities are as follows:

- Concurrent operation with other application programs, provided the system is configured with 28 Kbytes of memory
- Unattended operation, depending on hardware configuration
- Batch command stream
- Recovery restart
- Data compression/decompression
- Transparent data
- Automatic calling, depending on hardware configuration
- Autodial or autoanswer depending on hardware

DIBS-11 (Integrated Business System)

Digital's DIBS-11 Integrated Business System is a multitask business application package that consists of six fully integrated modules—Order Entry/Invoicing, Inventory Management, Accounts Receivable, Accounts Payable, Payroll, and General Ledger. These modules may be used separately or as part of a totally integrated system that shares information between jobs. When integrated, information from the separate modules is posted automatically to General Ledger accounts in the system. Integration keeps information current and reduces operator time.

Collectively, the DIBS-11 modules answer the data processing requirements of most business users. If additional capabilities are required, new software can be developed and easily integrated into the system. The modules can be selectively introduced into a business. This minimizes the disruption of ongoing operations by allowing the user to make adequate preparations and to complete the necessary training in phases. As the modules are introduced, they can be easily integrated with one another, permitting the sharing of data resources and system capabilities. Each module is thoroughly documented by comprehensive manuals, and while all were designed to function together, each can be used independently of the others if desired.

To simplify the use of the DIBS-11 accounting software modules, we have designed them using a common framework of standard routines and programs. When used properly, the routines provide system security, file protection, and a means of chaining programs together into job streams. They also serve as a means of assuring consistency of documentation and maintenance for any new software that might be added to the basic modules.

A further aid to programmers is the inclusion of various "hooks" in each of the modules. These hooks can be used to customize or expand the functions already provided. Many of the hooks are already predefined, making the programmer's task even easier. For example, certain data fields have been defined even though they are not used by the application programs.

All of the modules use a common set of external subroutines to handle processes that are frequently encountered. This not only helps to simplify the programmer's task, it also minimizes program length and helps to maintain the consistency of system design. Some of these subroutines include printer, terminal, and disk I/O routines; commonly used algorithms such as day or date calculations; and routines specifically designed for the multiple-branch environment.

Whenever possible, general functions such as file protection in multiuser environments are handled in common routines. This, too, relieves you of some design burden and allows you to concentrate on the unique aspects of the problem at hand.

The DIBS-11 modules employ essentially the same design concept. In general, all data files are either standard indexed file access or a fixed length, sequential file format. In addition to the regular application files, DIBS-11 maintains a number of special-purpose files that contribute to system functions. One is a menu processor that contains all of the screen prompts appearing in the user menus, along with associated program or menu names. Through the menu processor, screen formats and the sequence of program execution can be changed without having to write source code.

Others are a system file that in runtime use allows you to select and use system peripherals without the need for special programming; a table file of miscellaneous application data used by the modules (e.g., sales code tables, price rules, branch names); a user file that keeps track of which program is running or about to run, and any messages passed between programs; and a file that is updated with the current status of each data file and is the means by which data files are protected in multi-user environments.

Another important system feature is a subroutine that causes structures to be copied into source programs automatically. This allows common code record layouts and procedures, for example, to be shared by all application programs systemwide.

DIBS-11 is written in DIBOL. It is a customer-supported product which is distributed with source code.

DECtype-300

DECtype-300 is word processing software for CTS-300 which provides concurrent word and data processing. It is intended for use by organizations whose primary need is data processing. Systems equipped with DECtype-300 give users at every terminal word or data processing as needed.

DECtype-300 is a word processing application that produces documents. As you type text from a keyboard, DECtype-300 displays it on a video screen. Once the text is typed, DECtype files (saves) the document on a storage device, making it available for later use. At any time you can call the text back to the screen and use the keyboard to modify the document. You can tell DECtype-300 to print the document on any of several printers that may be attached.

DECtype-300 provides many options that let you produce documents that present your ideas as you intended them. You can highlight certain text by underlining or bolding it. You can type two or more characters in the same place on the paper, producing composite characters. You can use subscripts and superscripts for footnotes or mathematical formulas. You can right- or left-justify text, or center text between the margins. You can add tab spots and space between words and margins in any part of the document. You can indent paragraphs, switch between single-spacing and double-spacing, include tables in the text, and produce many other effects.

DECtype's "advanced features" make use of its general-purpose computer to meet applications other than word processing. You can insert information from a list document into the blanks in a form letter, producing "customized" letters, run it at the same time as other business applications, and perform simple mathematical calculations.

DECtype is easy for the new operator to use and understand. Wherever you must make major choices, DECtype-300 displays a "menu," describing all the options and indicating which letters to type to select each option. Before deleting information, DECtype either asks for confirmation or gives you a "second chance" to recover the information. When you give DECtype-300 an invalid command, it displays an understandable message telling you how to correct the problem.

DECtype is also optimized for the experienced user. The actual keystrokes required to invoke an option are minimal and easily memorized. DECtype-300 automatically wraps text so that lines of text will fit within the indicated margins, freeing you to look at the source document instead of the screen. If you should later change the margins, DECtype-300 automatically refits the text to conform to the new margins. DECtype ensures that questions of formatting do not slow down an experienced user during text entry.

QUILL

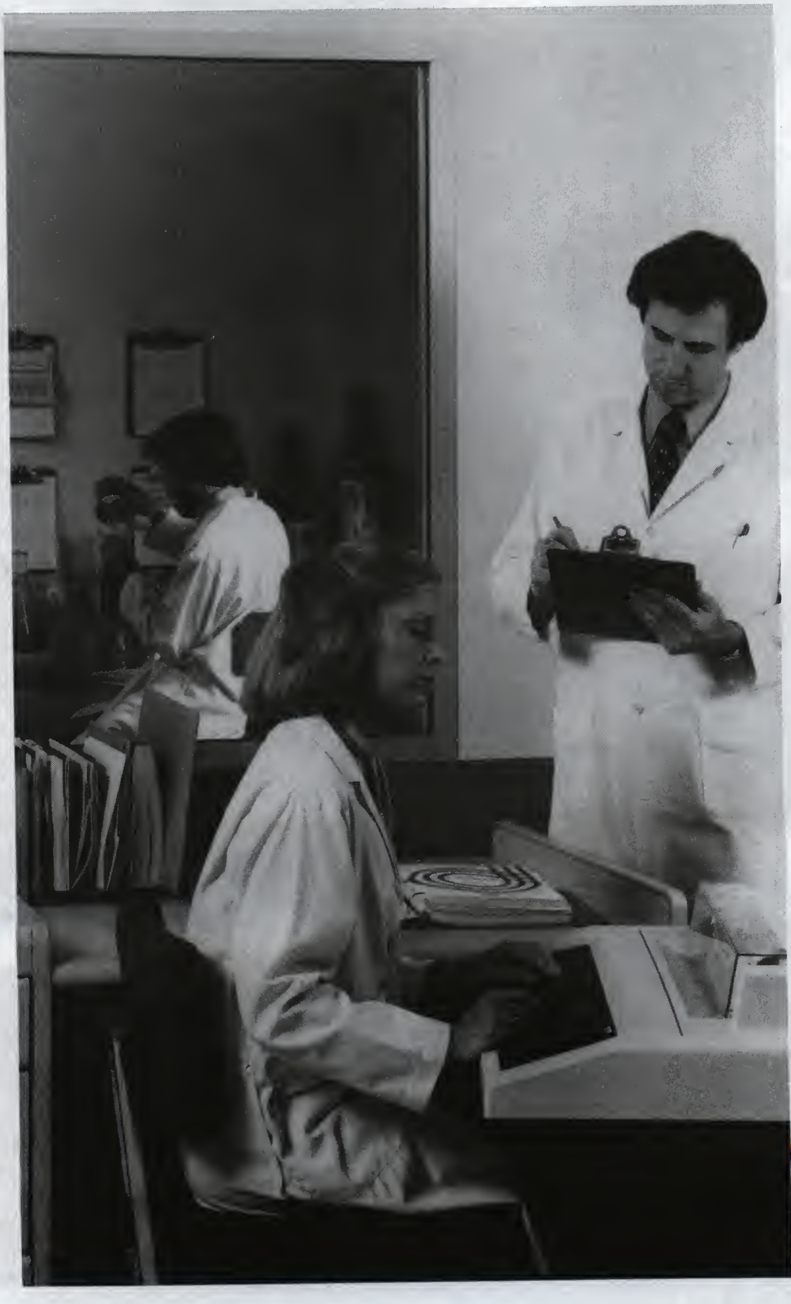
QUILL is a query/report writer program for business applications running on CTS-300. By locating the specific information you need, this program helps you create many types of reports and terminal queries.

QUILL is friendly and easy to use—you communicate with QUILL by using simple English-like commands. QUILL uses Dictionaries to describe the data files. Using the field names in the Dictionary the operator can use arithmetical, relational, and Boolean expressions to locate desired records. QUILL locates the records in the data file that satisfies the operator's request, and establishes a collection.

The collection is a much smaller file that is comprised of pointers to the physical locations of the desired records. QUILL uses the pointers in the collection to process the selected records. This is especially important for smaller systems with limited disk space.

Once the collection has been established the operator is ready to create the output in either a query list on the terminal, a simple to complex report for a printer or disk, or a List Document for DECtype-300. All of the commands that create any of the forms of output can be retained in a log file. To create the output again, simply type in a command and QUILL automatically goes to work for you. The logged commands will generate the output against the current, up-to-date data.

QUILL interfaces with DECtype-300, a full-featured word processing application. As easy as it is to create a simple query—QUILL "selects" the appropriate data from an established data file and creates a List Document for DECtype's List Processing Utility and Editor. Users will no longer have to maintain duplicate sets of data; one for data processing and the other for word processing. By using QUILL, the List Documents will be as current and up-to-date as the actual data file. No conversion is necessary. As soon as QUILL has created the List Document, DECtype can then access it immediately via the list processing routine or the editor.



Chapter 6

Digital Standard MUMPS

Digital Standard MUMPS (DSM-11) is a multiuser data management system that consists of an interactive, high-level programming language, a data management facility, and a time-sharing executive.

The language is an extension of the ANSI Standard Specification (X11.1-1977) for Massachusetts General Hospital Utility Multi-Programming System (MUMPS). MUMPS was originally developed at the Laboratory of Computer Science at Massachusetts General Hospital and was supported by Grant HS00240 from the National Center for Health Services Research and Development. System capabilities are heavily oriented toward string manipulation and relieve the user of any concern for programming peripheral devices or for structuring databases in the traditional sense.

Language processing by the system is interpretive. This greatly facilitates program development by eliminating the need to load editors, assemblers, or linkers. The DSM-11 application programmer need only be concerned with developing the proper logical hierarchy for a database and efficient logic for the application requirements.

The MUMPS language has its own stand-alone operating system. In addition to supporting the Standard MUMPS language and providing all operating system capabilities, the system affords a unique database structure. Data, referred to symbolically, is automatically stored and linked in sparse, hierarchical structures called M-trees. The physical and logical allocation of mass storage for the tree-structured database is handled completely by the operating system so the programmer can concentrate on application data relationships. The database can be made available to all system users or be restricted to a class of users.

The DSM-11 operating system runs on any of the MICRO/PDP-11, PDP-11/23-PLUS, 11/24, 11/34, 11/44 and 11/70 central processors. The system permits up to 63 simultaneous users, or partitions (see below), operating on any of up to 128 terminals.

A partition holds one active user's program, local data, and system overhead data. There is no fixed correspondence between terminals and user partitions; jobs can run without having terminals associated with them, and multiple terminals can be attached to one partition.

Partition assignment is performed dynamically either at login time or during execution. The recommended size for a partition is approximately four Kbytes. Partitions do not all have to be the same size; the maximum partition size is 16 Kbytes.

Additional features include:

- Dynamic file storage with variable-length string subscipts allows the user to easily modify or expand data elements in the existing database.
- A programmer can rapidly write, test, debug, or modify a program so that a working application is quickly established. A user can enter, inspect, or change data interactively and efficiently.
- A high-performance database handler uses an inmemory disk cache (with write-through) to allow efficient sharing of the data among all users.
- A system-level, transparent journal of database modifications can be maintained on either disk or magnetic tape.
- Distributed databases are managed using DMC11 or DMR11 high-speed data communication links.
- Output to devices (such as a printer) can be spooled.
- DSM-11 has automatic powerfail restart capability for processors with battery backup.
- DSM-11 provides bad-block management for all disk media.
- Online, high-speed database backup, disk media preparation, and tape-to-tape copying are standard DSM-11 features.
- Hardware device error reporting, system patching utility, and an executive debugger facilitate system maintenance.
- Streamlined system installation and system generation procedures allow the DSM-11 system to quickly adapt to any supported hardware configuration.

DSM-11 Users Gain Access to the System's Programs with a Special Login Sequence.

The login sequence involves one or two access codes (depending on the user's privileges). These codes, provided by the system manager, are the User Class Identifier Code (UCI), and the Programmer Access Code (PAC).

A UCI allows access to the programs and globals listed in the program and global directories for that UCI. A user who is permitted simply to run programs needs to know only the UCI and the name of the programs for that UCI.

Users who are allowed to create or modify programs and global files must know the system's PAC, which permits system operation in direct mode. A programmer can issue DSM commands at the keyboard, as well as create, modify, and delete data and programs associated with the user's UCI.

DSM-11 also employs a concept known as "tied terminals." An attempt to log-in at a tied terminal activates the task to which the terminal is tied and limits the user to the resources associated with that task. This capability gives the system manager an effective control mechanism for system access.

The Interpreter Saves Time for Programmers.

DSM-11 is implemented as an interpreter. This minimizes the programmer's time in solving a problem, the computer time needed to check it, and the elapsed time required to obtain a final running program. The interpreter is that part of the operating system responsible for these services.

The interpreter examines and analyzes all Standard MUMPS language statements and executes the desired operations. Each Standard MUMPS language statement undergoes identical processing every time it is executed by the interpreter. Intermediate code is not generated. Comprehensive error checking is also performed to ensure proper language syntax.

In addition, the interpreter stores and loads programs through the disk storage system. During program execution, the interpreter can overlay external program segments invoked by an active program. Proper linkages are set up to return to the invoking program when execution of the segments terminates.

A number of major advantages are obtained from the interpreter. Programs written in an interpretive language do not require any compilation or assembly. Error comments during execution are printed at the programmer's terminal and allow quick recovery, program modification, and reexecution. All program debugging and modification operations are performed directly at the terminal in the MUMPS language.

Almost any MUMPS command or function can be executed from the keyboard in direct mode. When a command is entered, the MUMPS language interpreter immediately executes it and gives the appropriate response to the programmer. A command line can consist of several Standard MUMPS commands and arguments, comments, and data. For example, the programmer can enter the command line:

```
> WRITE "7+5=",7+5
```

This command tells DSM-11 to print the characters "7+5 =" on the terminal, evaluate the arithmetic expression 7+5 and print the result on the terminal. DSM-11 responds by typing:

```
7+5=12
>
```

The DO command tells DSM-11 to begin executing at a specified label of the stored program. It will continue until it encounters a control command such as GOTO or QUIT, or arrives at a point where there is nothing else to interpret.

To create a program, the programmer enters one or more lines of MUMPS commands. Once a program has been created, the programmer can store the contents of the partition's program buffer on disk or on a secondary storage device such as magnetic tape. The program can then be reloaded into the program buffer from the disk or secondary storage. When a program is loaded in the program buffer it can be modified by adding new lines or by replacing, deleting, or modifying existing lines of code.

DSM-11 Accesses Terminals and Ancillary I/O Devices.

In addition to the disk space reserved by the DSM-11 database supervisor, DSM-11 allows access to terminals and ancillary I/O devices such as the lineprinter and magnetic tape. Each I/O device has a unique identification number in the system.

The OPEN command establishes ownership of terminals and ancillary I/O devices. Then I/O may proceed, using available I/O commands. In general, the programmer need not be concerned with specific characteristics of I/O devices, since data transfers consist of ASCII strings not greater than 255 characters. There are, however, certain physical operating characteristics that may be of interest to the programmer, such as rewinding a mag tape or form feeding on the lineprinter.

The commands affecting input/output operations to the terminals and ancillary devices are: READ, WRITE, WRITE *, ZLOAD and ZPRINT. The WRITE command is used to output both local and global data, as well as literals, constants, and format control characters. The WRITE * command is used primarily to take advantage of I/O device special features, which are specified, generally, by nonprinting ASCII codes. The WRITE * command accepts numeric arguments, of which the low-order seven bits are taken as the decimal repesentation of the ASCII code. For example, the command W *10 is used to output a line feed character.

DSM-11 also has three special "devices." They are the Sequential Disk Processor, the CPU to CPU device, and the Job Communication device.

The Sequential Disk Processor (SDP) allows the user to physically access the disk as an assignable sequential I/O device. The SDP can access only the disk space that is explicitly set aside for its use. Other disk space, including the global database structure, cannot be accessed. Sequential disk processing allows the user to impose any file structure on the SDP space.

The CPU to CPU device is a DMR11 synchronous interface, full- or half-duplex, that connects one DSM-11 CPU to another CPU. The other CPU does not necessarily have to be a DSM-11 system, but does have to recognize DDCMP protocol. This device allows a MUMPS program to communicate with a program running on another central processor.

In-memory job communication (Job Comm) permits jobs to send information to other jobs without using the disk. Communication occurs through a series of pseudo-devices that are used in pairs; even-numbered devices are "receivers" and odd-numbered devices are "transmitters."

DSM-11 Spools Output to Line Printers.

The spooling device is a file-structured mechanism used for temporary storage of information. Typically, a user directs the output of several programs to separate files on this device. The files are then processed one at a time by a de-spooling program that writes them to an output device.

To aid in classifying spool files, each has a destination code and its own unique file index number. The destination code is a value, in the range of 1 to 255, recorded in the directory entry for easy access. By using this code, a file can easily aid in retrieving a particular group of files.

Journaling Provides a Backup for Your Database.

In the DSM-11 system, any item that is changed on the database may also be written to a disk or magnetic tape as a journal record. Even if a disk failure occurs, it is always possible to restore the journal tape entries onto the previous backup copy and bring the system up-to-date as of the time of the failure. Journaling runs at the system level, and is transparently built into the operating system so that DSM-11 programs need not be modified or specially written to handle journaling. The desired database transactions are recorded automatically onto the journaling media.

The Symbolic MUMPS Debugger Lets You Interactively Set or Clear Breakpoints.

The DSM-11 debugger retains the current program context, allows single program execution, and provides a trace facility. The debugger can be entered during program execution when logged into DSM-11 in programmer mode by typing <CTRL>B. The debugger is invoked after the next MUMPS command is executed and the prompt DB> appears. The ZGO command restarts program execution, and a <RETURN> forces single-step execution of MUMPS commands.

DSM-11 Uses Mapped Routines.

DSM-11 permits the user to set up an area in physical memory to store the more frequently used MUMPS routines. A utility provides a means to build a mapped routine set. Once the set is built, it may be loaded into memory. When a MUMPS routine is called, the routine map is first searched before accessing the disk. Routines are executed from the map without copying them into the job's partition, resulting in both disk and CPU performance requirements.

Data Management Uses Data Storage Elements, Variables, Disk Structure and Global Arrays.

In DSM-11, all data is referenced symbolically in the context of hierarchical global variables and arrays. The content and structure of the tree-structured global arrays are logically mapped into the system's physical storage medium.

All user data, numeric or string, is stored in the system as ASCII character strings. DSM-11 interprets these strings in one of two ways: as numbers, such as those used in calculations, or as strings, such as names and addresses.

Numbers in DSM-11 are signed numbers which can be up to 32 significant decimal digits long. Examples of numbers are:

```
2.08
151.95
403.333
.6379465
```

DSM-11 string data is any contiguous series of legal DSM-11 characters that are to be considered a single data entity. Strings in DSM-11 can be up to 255 characters long. Examples of strings are:

```
HELLO, MY NAME IS
55 SECONDS
2,564,843,485,076,193
FRIENDS, ROMANS, COUNTRYMEN ...
FROP%X10.CF
```

Variables

Program data values can be expressed as literals, constants, or variables. Two types of variables can be created in DSM-11 programs: local variables and global variables, each of which may be subscripted. Variables can be created, modified, and deleted using the SET, READ, and KILL commands.

A subscript is a value enclosed in parentheses and appended to a variable name. It uniquely identifies data elements that are to reside under that variable name. All subscripted variables residing under a common name are collectively referred to as an array. An array can consist of variables with more than one level of subscripting; when more than one level is used for global array subscripts, they are separated by commas.

DSM-11 uses sparse arrays that contain only those elements explicitly defined. Unlike other languages that may require a declaration of the maximum size of an array to preallocate space, DSM dynamically allocates storage for all array elements only as needed.

Local variables, which are variables that reside in the same partition as the commands that created them, are used as scratch or transient data. They are accessible only to programs running in the same partition. Variables such as ABC, R45, X, %D have no subscripts and are called simple variables. Subscripted variables can have multiple levels of subscripting, with numeric or string subscripts, such as ABC(2), R49("LIST"), ABC (4+B (C*D)/X,89).

Global variables are subscripted arrays stored on disk. External to a program's partition, they provide a common database available to all programs authorized through the system protection scheme. There is no logical limit to the number of subscripts that can be used. Like subscripted local variables, global arrays also reside in sparse arrays and are created simply by reference in a program. Each global array name is similar to a local variable name, but is always preceded by the circumflex symbol (ˆ).

The DSM-11 Disk Structure and Global Arrays

Disk volumes allocated for the storage of DSM-11 globals and programs are the primary storage media used by the DSM-11 system. Each UCI defined by the system manager has two directories associated with it: the global directory (that is, the file directory), and the program directory.

The system manager, who can locate the directories on any disk unit in the system, can also limit program and global storage to specific disk units.

Globals are logically organized as multidimensional tree-structured arrays. An element of an array has a logical name consisting of the global name and the subscript(s) uniquely identifying the element. For example, ˆABC(2,3.4,"JONES") is the name of the element in the global called ABC with a first subscript of 2,its second subscript is 3.4, and its third subscript is "JONES." The elements of a global array are called nodes. The user's global directory contains the names of all the globals it can reference, as well as pointers to the tree structure for each of the globals.

DSM-11 Language Utility Programs Provide You with the Tools to Maintain and Service the System Efficiently.

All DSM-11 utilities are written as Standard MUMPS language programs, and as such can be easily modified and extended to suit the needs of a particular installation. The utility programs consist of two operationally distinct groups: system utility programs and library utility programs. The system utility programs provide functions for use by the system manager, are under the control of the system UCI, and are accessible only to those individuals possessing the system UCI code.

Library utility programs provide general services that are available to all system users, regardless of UCI. These programs also reside under the system UCI but employ a naming convention that distinguishes them from system utilities.

The DSM-11 backup utility programs allow the user to save significant data from DSM-11 disks. Some of the other utility programs include functions to:

- Label disks and mag tapes for identification purposes
- Format and test disks; initialize disks to be used in a DSM-11 environment
- Make exact image copies of mag tape and disk volumes

- Allow the direct allocation or deallocation of individual blocks on a DSM-11 disk
- Check the integrity of the database

The MUMPS Language Consists of Expressions, Commands, Functions, and Special Variables.

An *expression* is a value description that can be made in the Standard MUMPS language, including any legal combinations of operands and operators. The following are examples of expression elements:

123.34	constant
ABC	simple variable
"ABCD"	literal
MX(5)	local subscripted variable
XYZ(2,5)	global variable
$LENGTH(Z)	function reference
(A+B-(C/D))	subexpression

The operators in an expression serve to represent the various arithmetic and logical computations of the Standard MUMPS language. Following is a list of Standard MUMPS expression operators:

TYPE	SYMBOL FUNCTION
Arithmetic	+ Addition
	- Subtraction or Unary minus
	* Multiplication
	/ Division
	# Module
	\ Integer divide
Relational	< Less than
	> Greater than
	= Equality
Boolean	& AND
	! OR
	' NOT
String	[Contains
	] Follows

relational	
	? Pattern verification
	= Equality
String	– Concatenation
concatenation	
Indirection	@ Indirection

Indirection is denoted by the character @ followed by an atomic expression. The value of the expression is substituted for the occurrence of indirection before the rest of the line is interpreted.

Of special importance are the relational string operators. They provide facilities for determining the characteristics of string data. The operators return true or false results. They are:

- String Contains ([)— The string specified by the left operand is examined for the occurrence of the string specified by the right operand.
- String Follows (])— The string specified by the left operand is compared character-for-character with the string specified by the right operand to establish relative position according to the ASCII collating sequence.
- Pattern Verification (?)— The string specified by the left operand is examined for the occurrence of the character patterns specified by pattern specification codes.

A *command* is the basic unit of expression in the Standard MUMPS language. A command is a mnemonic that symbolizes the action to be performed, such as GOTO or SET. The command name can be abbreviated to one letter. It usually takes one or more arguments that specify the objects of the action to be performed. Several Standard MUMPS commands can be present on a command line.

An optional Boolean-valued expression preceded by a colon can be used as part of an argument to specify conditional execution. For example, "GOTO LOOP:A>B" means that control is transferred to "LOOP" if A is greater than B.

The following is a list of DSM-11 commands:

BREAK	Suspends execution of a routine and brings the terminal back to direct mode.
CLOSE	Releases one or more designated devices from ownership.
DO	Initiates execution of DSM-11 routine at the label specified, with an implied return.
ELSE	Conditionally executes the statements following it.
FOR	Produces looping by repeating commands residing on the same line for a specific set of variable values.
GOTO	Interpreter execution is transferred either to a specified line or routine.

HALT	Ends your use of DSM-11.
HANG	Suspends program execution for a specified time interval.
IF	Permits the conditional execution of the commands or statement that follow it.
JOB	Starts a specified routine in a new partition.
KILL	Deletes the specified local and global variables.
LOCK	Makes a particular variable or node of a variable unavailable for locking by another user.
NEW	Saves all local variables, restores them at the next QUIT.
OPEN	Obtains ownership of one or more devices.
QUIT	Terminates the current flow of execution.
READ	Receives data from the current device.
SET	Assigns the value of an expression to a variable.
USE	Designates a specific open device as the current device for input and output.
VIEW	Allows you to read and write data to disk storage or to alter locations in memory.
WRITE	Sends data and/or control information to the current device.
XECUTE	Executes DSM-11 statements that result from the evaluation of an expression.

Z-commands are the DSM-11 extensions to the Standard MUMPS language:

ZALLOCATE	Allocates specified variables.
ZBREAK	Turns on, turns off, and controls the DSM-11 debugger.
ZDEALLOCATE	Deallocates all variables previously locked with ZALLOCATE.
ZGO	Resumes execution of a routine after a BREAK command.
ZINSERT	Inserts a line into the routine currently in memory.
ZJOB	Starts a specified routine in a new partition.
ZLOAD	Loads a routine into memory.
ZPRINT	Writes the current routine to the current output device.
ZREMOVE	Deletes the current routine or specified lines in the current routine.
ZSAVE	Stores a routine in your routine directory.
ZUSE	Allows temporary use of a terminal device owned by another job.
ZWRITE	Writes all local variables to the current output device.

A *function* performs an operation and returns a value, based on the outcome of that operation. The following is a list of available functions:

$ASCII	Returns the ASCII code of a string character as a decimal integer.
$CHAR	Translates a decimal integer into a ASCII character.
$DATA	Returns an integer indicating whether a specified node contains data, or has descendants.
$EXTRACT	Returns a substring of a string expression, selected by position number.
$FIND	Returns an integer specifying the end position of a specified substring.
$JUSTIFY	Returns a string, right-justified in a field of a specified length.
$LENGTH	Returns number of characters in a string.
$NEXT	Returns the subscript of the next sibling in collating sequence to the specified global or local node.
$PIECE	Returns a substring from a specified string selected by delimiter.
$RANDOM	Returns a pseudo-random integer uniformly distributed in a closed interval.
$SELECT	Returns the value of the first expression in its argument list when a matched truth value expression is true.
$TEXT	Returns the specified line from the routine currently in memory.
$VIEW	Returns an integer between 0 and 65535, equal to the contents of the memory location specified in the argument.

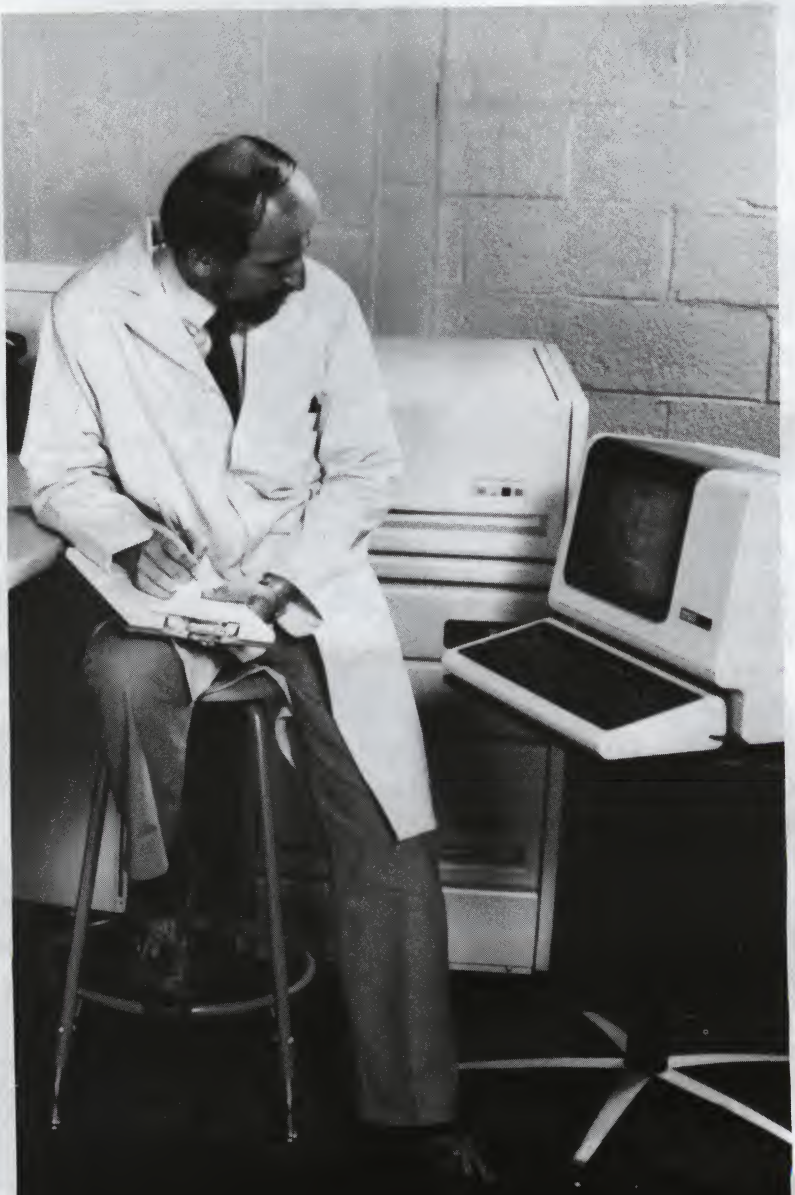
Certain functions, called *$Z-functions*, are DSM-11 specific. They are provided as extensions to Standard MUMPS, giving more options to the user.

$ZCALL	Provides a general-purpose function call to user-written routines.
$ZNEXT	Performs a physical scan of a global array.
ZORDER	Returns full reference of next node to node specified.
$ZSORT	Returns the subscript of the next sibling in string collating sequence of a specified array node.
ZUCI	Returns the UCI number, given the UCI name; or returns the UCI name, given the UCI number.

A number of *special variables* that are reference-only are defined within the system to control the flow of information and to provide system information to Standard MUMPS programmers. These variables are maintained and updated by

the system for each job partition. The following is a list of the special variables, including the $Z special variables.

$HOROLOG	Contains the current date and time.
$IO	Identifies the current I/O device.
$JOB	Contains the job number.
$STORAGE	Contains the amount of free space available within the current partition.
$TEST	Contains a truth value computed from execution of the most recent IF command, containing an argument, or an OPEN, LOCK, or READ with a timeout.
$X	Contains a non-negative integer value equal to the next column position to be output.
$Y	Contains the current line number.
$ZA	Contains status or error information for the current device.
$ZB	Contains status information on the current device, in the form of a numeric value.
ZBREAK	Contains a set of routines reference to a breakpoint.
$ZERROR	When an error occurs, this variable contains the line segment that caused the error.
ZORDER	Contains the value of the next global node in sequence after the current global reference.
ZREFERENCE	Contains the current global reference.
$ZTRAP	Contains a reference to a line and/or routine to which you want control to pass in the event of an error.
$ZVERSION	Contains the name and version of your DSM system.



Chapter 7

MicroPower/Pascal

MicroPower/Pascal has the Tools You Need for Real-Time Applications.

MicroPower/Pascal is an advanced software tool kit for developing PDP-11 (Q-BUS) based microcomputer applications. It includes a high-performance, optimizing Pascal compiler, a modular executive, and all the tools you need to create concurrent, real-time application programs. You create these applications on a PDP-11 (or VAX/VMS) host system for execution and debugging in a separate target microcomputer that can be any Digital Q-BUS processor from the FALCON SBC-11/21 to the PDP-11/23-PLUS. Each application is constructed especially for its target system, with the exact set of operating system services needed.

At present there are three MicroPower/Pascal products: MicroPower/Pascal-RT, MicroPower/Pascal-RSX, and MicroPower/Pascal-VMS. Both MicroPower/Pascal-RT and MicroPower/Pascal-RSX develop applications using a PDP-11 host system, while MicroPower/Pascal-VMS is used for application development on the VAX family. Given the same set of inputs, all three products produce identical target runtime applications.

MicroPower/Pascal is particularly suited for dedicated, real-time microcomputer applications such as process control, instrumentation, and robotics.

Target Environment

- Pascal extensions support real-time multitasking
- Applications reside in ROM and/or RAM
- Assembly language interface allows MACRO-11 programming
- Applications can be debugged interactively using a symbolic debugger
- File system is compatible with RT-11
- Device drivers support many Q-bus interfaces
- Applications can be transported from the host to the target by: down-line loading ROM, or bootable media

Host Development Environment

- Optimizing compiler produces fast, compact object code executable on any Digital Q-Bus microcomputer.
- MicroPower/Pascal-RT or MicroPower/Pascal-RSX for PDP-11 host; MicroPower/Pascal-VMS for Vax host.
- Symbolic Debugger (PASDBG)
- Incremental Linker (MERGE/RELOC/MIB)
- Copy bootable image to mass storage device (copy B)
- Customer installability
- Utility Command Procedure to build applications

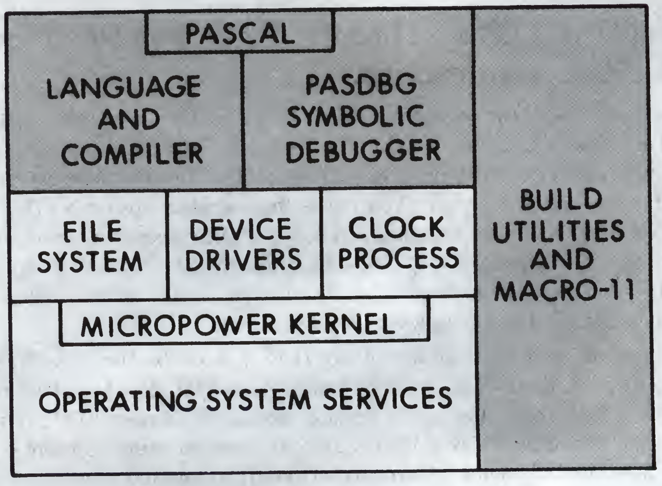


Figure 7-1 MicroPower/Pascal Components

Those components that reside in the host are shown by background shading. Those components not shaded reside in the target system (only those components and services that your application requires are included).

MicroPower/Pascal Supports Multitasking.

MicroPower/Pascal is a microcomputer software architecture that extends standard Pascal to incorporate system implementation language capabilities and support concurrent programming (multitasking). MicroPower/Pascal lets you code micro-

computer applications that have direct access to device registers, and can perform interrupt handling. Built-in procedures allow easy access to the file system, clock process, device drivers, and the operating system services of the kernel.

When you team MicroPower/Pascal with your PDP-11 system, you will have a complete hardware/software package with everything you need to build quality microcomputer applications. MicroPower/Pascal builds a complete and powerful realtime software application that is so compact it could reside in as little as eight Kbytes of memory. For your most complex applications, you can address up to four Mbytes of memory on the LSI-11/23.

Host and Target Processors

MicroPower/Pascal uses a two processor development environment: a host, where the compiler and development utilities reside, and a target Q-bus processor, where the compiled code and kernel execute. The host can be either a PDP-11 running the RT-11 extended memory (XM) operating system, RSX-11M or RSX-11M-PLUS, or a VAX running the VMS system. This provides the most effective work environment for developing target system programs. You can transport your final application program ro the target microcomputer by one of three methods: writing it into read-only memory (ROM), down-line loading it over a serial line, or recording it on magnetic storage media such as a floppy disk or tape cartridge which you can bootstrap on the target.

Concurrent Programming Capability

Concurrent programming means your Pascal source code is structured into independent parts called processes, that appear to execute simultaneously. Each process competes with all other processes for control of the target processor, but cooperates with all other processes in manipulating shared resources such as memory and peripheral devices.

Target System Kernel

MicroPower/Pascal processes have no need for a conventional operating system. Instead, every application contains its own customized set of routines, the kernel, that supports them. MicroPower/Pascal automatically selects those operating system services that your application requires, from a library in the PDP-11 host computer, and places them in a kernel. By including only required system services, the kernel and the application it supports make the most efficient use of memory.

The target system kernel lets applications access device registers, the file system, the clock process, and device drivers. The kernel also performs interrupt handling and lets concurrent tasks share the target processor.

Synchronizing Processes

Key to this concurrent application design is the mechanism for sharing control of the CPU and other common resources, such as data areas and peripheral devices.

In the MicroPower/Pascal target system, executing processes are synchronized by *semaphores.*

Semaphores are global data structures that are manipulated by two or more processes. They act like flags that are raised and lowered by processes to signal their progress to other processes. You create semaphores in a source program to guide the response of the entire application to external, real-time events. Semaphores can delay a process until another process sends it a signal to proceed. This lets two processes share access to common data, without corrupting the data.

Application Development Tools

MicroPower/Pascal utility programs construct your application and load it into the target system memory. They accept as input object modules of compiled or assembled source code contained in files. The utilities also accept object modules from various module libraries. They link these object modules with a customized kernel to create the application.

Micropower's modular architecture makes it easy to test, debug, update, and expand your applications. It also reduces memory requirements for applications without sacrificing the ability to build large, versatile, four Mbyte configurations.

The MicroPower/Pascal utilities include:

- MERGE
- RELOC
- MIB
- DLLOAD
- COPYB

MERGE accepts multiple object modules containing compiled or assembled source code and data as input. It automatically combines program sections (p-sects) with identical names from all input object modules. MERGE also uses the symbol tables created in each object module during compilation to resolve intermodule references. For every reference to a declared EXTERNAL name, MERGE looks for a declared GLOBAL definition in the other object modules. Undefined symbols are flagged.

MERGE can be used to build a customized kernel which contains *only* the system services issued by the application program. The kernel is not relocatable; it must start at zero.

RELOC is the utility program that assigns addresses to the entities within a merged object module. It produces a process image module with one base address. This base address is the module's correct location within the application's memory

range. With RELOC, you can directly specify the virtual base addresses of different parts of the application. RELOC also separates p-sects according to their Read-Only or Read/Write attributes, and modifies the code sections to execute properly at their assigned addresses.

The *Memory Image Builder (MIB)* utility creates the executable application by placing all its components into one structure, called the memory image. This memory image includes each merged, relocated piece of the application with intermodule references resolved. The MIB utility lets you control the placement of pieces of the application in memory.

DLLOAD lets you load your application into target system RAM over a communication link (DLV11 serial line interface) from the development system. When you run DLLOAD at the host, the bootstrap program in the target LSI-11's ROM begins running as soon as you power up the target. The target system boots the application from the host into its memory and begins to run it. (This tool is not available with VAX/VMS.)

COPYB generates a bootable media volume for either a TU58 tape cartridge or an RX02 floppy diskette. You can then use this volume to load your application into the target system.

Another way to load an application into the target system is to burn the application program into a ROM chip and install the chip into the target. (ROM programming hardware and software, however, are not included with Micropower/Pascal.)

MicroPower/Pascal Compiler

The MicroPower/Pascal compiler runs on any PDP-11 with the RT-11 XM, RSX-11M, or RSX-11M-PLUS operating system (or VAX/VMS) and at least 128 Kbytes of memory. This compiler contains the most sophisticated global optimization available. It inspects all program modules for redundancy and produces code that executes almost as quickly as MACRO for a ROM and/or RAM environment. It significantly reduces the size and improves the speed of application programs by efficiently using the LSI-11's general purpose registers and hardware stack capabilities. The compiler provides for separate module compilation and efficient interfacing to MACRO-11 assembly language routines. High-level language access to the modular run-time routines (kernel) means more efficient, and less expensive, system level software development with little need for MACRO coding. You need not get involved in intricate machine instructions, nor must you learn separate operating system functions.

Compliance with International Standards Organization (ISO) specifications allows using the source code from other ISO compilers with full compatibility.

An extensive library of Object Time System (OTS) routines provides the compiler with runtime support for Pascal functions including utility and I/O routines and arithmetic routines such as floating-point support.

Symbolic Debugger

The Symbolic Debugger program, PASDBG, residing in the host system, downline loads and remotely controls the execution of applications in the target processor. This is accomplished without expensive in-circuit emulation hardware. Not only does it allow full program debugging in the original Pascal language terms, but it also enables the programmer to view the target's kernel and concurrently executing processes. Debugging the application in the actual target system assures a more reliable final product.

Although PASDBG resides in the host, debugging an application program requires some additional code in the target. Building an application for debugging adds about 800 words to the size of the application. Setting the debug switch also increases the size of the code generated when compiling a module. However, you only set the debug switch on modules you are debugging. You add undebugged modules to the application a few at a time, debugging each, then rebuilding without debugger support. In this manner, the entire application is built from small, debugged pieces.

MACRO-11 Source Libraries

The MACRO-11 interface to the runtime system is included in the form of a macro library, which is useful in developing MACRO-11 programs. Using MACRO-11 modules lets you handle the most time-critical applications.

Device and File Support

MicroPower/Pascal provides precompiled driver processes that act as interfaces between your application and various Digital devices (such as the RX02 floppy disk drive). You can also include a file system process and modules that allow you to create, access, and maintain data on target mass storage devices in a format compatible with RT-11. Because driver processes and the file system are both fully accessible from your Pascal source code, I/O operations are much easier.

The MicroPower/Pascal Operating Environment Covers a Wide Range of Systems.

Host Development System

The RT-11 XM operating system comes with the MicroPower/Pascal-RT software package. This package will run on any of the following PDP-11 or LSI-11 systems:

- MICRO/PDP-11, 11/23, 11/23-PLUS, 11/24, 11/34, 11/35, 11/40, 11/44, 11/45, 11/50, 11/55, 11/60, or 11/73
- EIS, KT-11 memory management unit and line frequency clock

- Minimum of 128 Kbytes of memory
- Two serial-line interfaces of the DL11 or DLV11 family (with cables) for the console terminal and the host/target communication line
- Console terminal: VT52, VT100, LA34, LA36, LA120
- For non-MICRO/PDP-11 systems, two random-access, mass-storage device drives (RK06, RK07, RL01, RL02, or RX02), at least one of which must be either an RL02 or an RX02

Note: MicroPower/Pascal is shipped as files on one of three media—RL02 disk, RX02 floppy diskette, or RX50 floppy diskette.

Target Environment

MicroPower/Pascal applications will run on any of the following Q-bus processors:

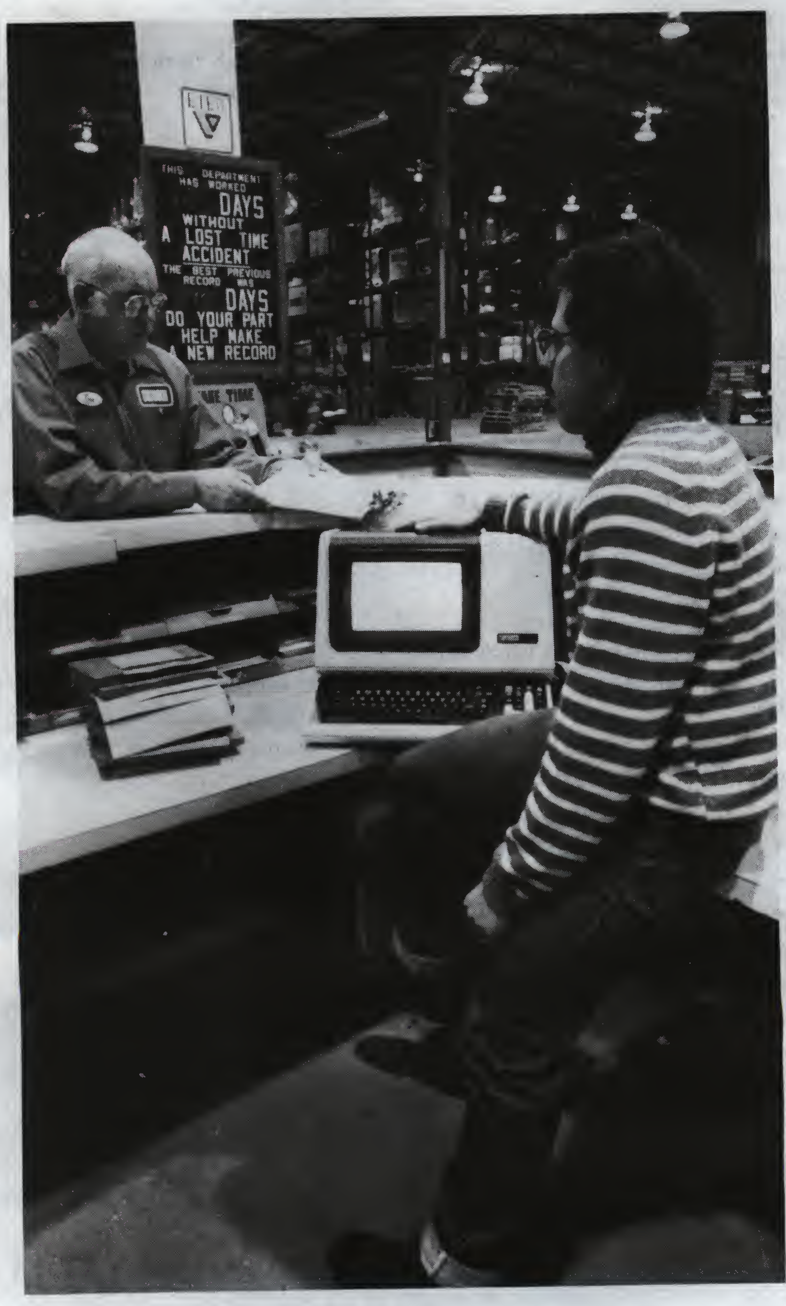
- LSI-11, 11/2, 11/23, 11/23-PLUS, 11/73
- PDP-11/03, 11/23, 11/23-PLUS
- Falcon SBC-11/21 (KXT11-A2 chips required during debugging)
- MICRO/PDP-11
- T-11 chip

A serial line interface is required to use PASDBG.

Maximum memory on a PDP-11/23 or LSI-11/23 with 22-bit addressing is four Mbytes. Minimum memory on the Falcon, PDP-11/03, or LSI-11/2 is eight Kbytes.

The following devices are supported in the target environment:

- MRV11-C, MRV11-D PROM modules
- MSV11-D, -L, and -P RAM modules
- MXV11-A, MXV11-B multifunction modules
- DLV11, DLV11-E, F, and J asynchronous communications interfaces
- DRV11, DRV11-J, parallel I/O devices
- TU58 DECtape II, RX02 floppy disk, RLO2 hard disk
- MICRO/PDP-11
- KWV11-C Realtime clock
- ADV11-C analog input module
- AAV11-C analog output module
- AXV11-C analog input/output module


THIS DEPARTMENT HAS WORKED
DAYS
WITHOUT
A LOST TIME
ACCIDENT
THE BEST PREVIOUS RECORD WAS
DAYS
DO YOUR PART
HELP MAKE
A NEW RECORD

Chapter 8

V7M-11

V7M-11 is Derived from the UNIX™ Time-sharing System.

The V7M-11 operating system is part of an emerging family of Digital software products collectively known as *ULTRIX*. ULTRIX products provide a flexible and elegant programming environment and are based on the various UNIX operating systems developed in the late 1960's at Bell Laboratories and the University of California, Berkeley. Today, there are a number of variations of the UNIX operating system available, as well as a growing number of lookalike products.

V7M-11's Enhancements are Engineered for Maintainability.

V7M-11, or Time-sharing System Version Seven, is Digital's ULTRIX operating system for the PDP-11 family. Based on the Seventh Edition (V7) of the UNIX operating system, it's a general purpose, multi-user, interactive system with a broad range of applications in educational, industrial, and commercial environments. V7M-11 enhancements are engineered to achieve a system with maximum maintainability. In addition to the numerous enhancements found in the Seventh Edition, V7M-11 offers bug fixes and other features found on the UNIX operating system including:

- Bourne Shell
- Shell Scripts
- Pipes
- C Compiler
- Assembler

Digital Offers Revisions to the Seventh Edition.

In addition to the V7 offerings, V7M-11 offers:

- Improved fault tolerance
- Disk bad block replacement
- Fully automated system generation

UNIX™ is a trademark of Bell Laboratories.

- System tuning
- Processor and peripheral device support
- VI editor
- Overlay kernel for CPUs without separate I & D space
- Improved UNIBUS map allocation algorithm
- Special files
- File system table
- Crash Dump Analyzer
- System management commands

V7M-11 languages include C; FORTRAN-77; RATFOR, which adds a C type control structure to FORTRAN; and a BASIC-like interpretive language. Software tools include a compiler-writing system, document preparation programs, information-handling routines, and graphics support.

Improved Fault Tolerance

The V7M-11 kernel provides complete fault tolerance and supplies more complete error information when a fault does occur. All system and device error messages have been documented.

Disk Bad Block Replacement

V7M-11 has a bad block replacement strategy for RK06/7, RM02/3/5, and RP04/5/6 disks. The drivers for these disks have been modified to read the bad block file and automatically replace any bad blocks. This bad block replacement is transparent to both the operating system and the users.

V7M-11 bad blocking includes two standalone programs: bad blocks scan (BADS) and disk initialization (DSKINIT). It also includes a bad block status command (BADSTAT), which monitors and displays the number of replacements performed on each bad block. This command allows the system manager to assess the effect of bad block replacements on system performance.

Automated System Generation

An interactive program called *SYSGEN* automates system generation. By asking a series of questions, SYSGEN lets you configure the system, create a configuration file, and install the kernel. SYSGEN includes on-line help to guide the user through the entire system generation process.

System Tuning

In V7M-11, values for parameters that define kernel-internal data structures, such as the process and inode tables, can be changed during system generation without recompiling any source code modules.

Processor and Peripheral Device Support

V7M-11 runs on all memory-managed PDP-11 processors, supports a wide variety of peripheral devices, and is fully supported by Digital. It also features the new *Digital Storage Architecture* (DSA) disks, which use the Mass Storage Control Protocol (MSCP) and are compatible with any other disk conforming to MSCP specifications. The design, packaging, and documentation of V7M-11 make it possible to be customer installed. Installation can also be purchased from Digital Software Services.

V7M-11 is distributed on three types of media: 1200 foot magtape, RL02 disk pack, and RX50 five inch floppy diskettes. The distribution magtape contains a boot and other standalone programs, a dump/restore image of the UNIX root file system, and a user file system. The RL02 distribution has a single RL02-EF disk pack containing the UNIX root and user file systems. RX50 diskettes contain the same files as magtape but are for the MICRO/PDP-11 only.

VI Editor

V7M-11 comes with the full screen editor based on University of California, Berkeley, Version 3.7. TAGS and LISP code are not included, however.

Overlay Kernel for Processors without Separate I and D Space

Processors that lack separate Instruction and Data space normally limit the kernel to 48 KBytes of address space. V7M-11 gets around this limitation by using a text overlay kernel with mapped buffers. Up to twelve users can be supported this way, consistent with CPU power and response-time requirements.

UNIBUS Map Allocation

V7M-11 uses a UNIBUS map algorithm which allows four devices to use the map concurrently. This increases both the amount of UNIBUS device I/O overlap and system I/O throughput.

Special Files

V7M-11 provides a *Create Special File* (CSF) command. This command lets all special files needed to access a device be created with a single command.

File System Table

A *file system table* (/etc/fstab) contains the names of the system and user file systems as well as the names of the directories where they're to be mounted. All system commands requiring file system names as input have been modified to use the names in the file system table as their default file system names.

Crash Dump Analyzer

The Crash Dump Analysis Program (CDA) provides information about system crashes in a dump analysis report. The CDA report includes a memory usage map and information on unlogged errors, hardware traps (also known as panic traps),

active processes, I/O buffer cache usage and many of the operating system's internal data structures.

System Management Commands

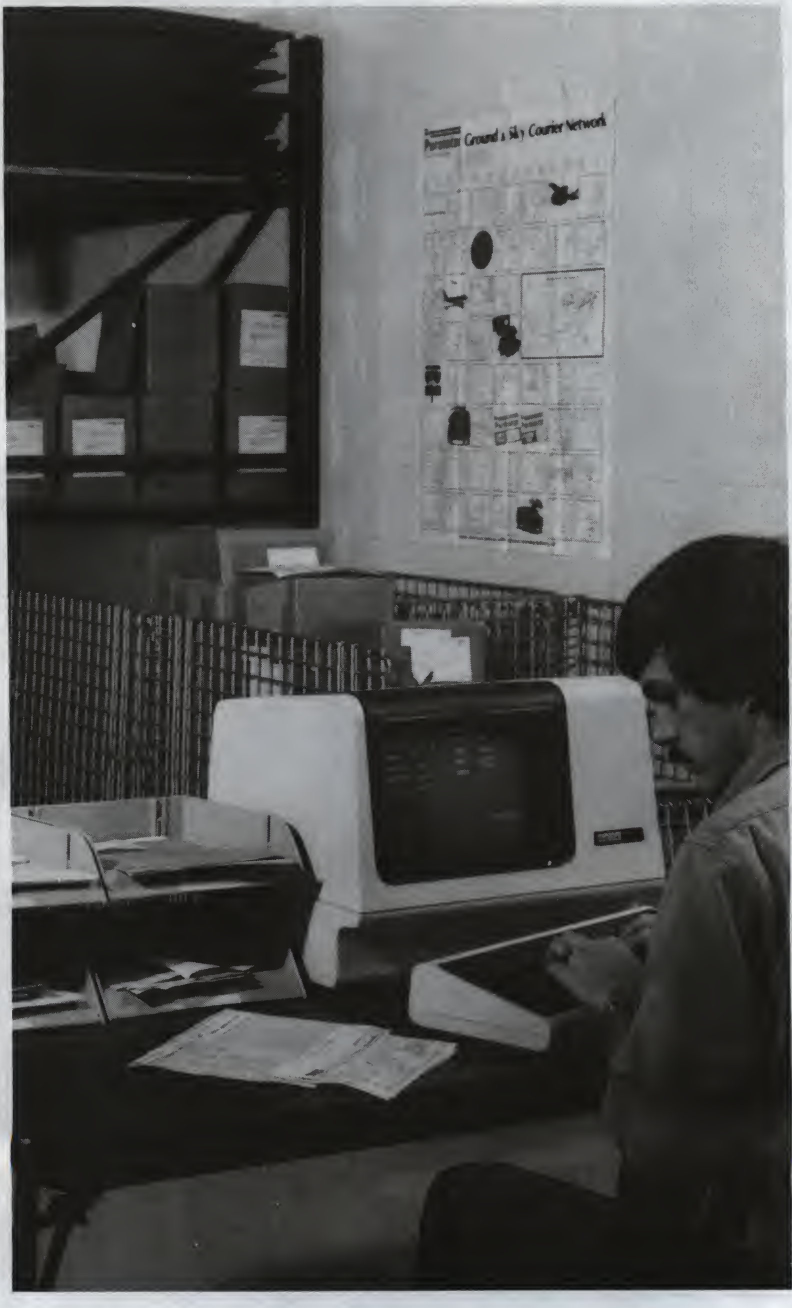
V7M-11 includes several commands designed to aid system monitoring and file system maintenance. These include:

- IPATCH, which dumps and/or modifies an inode.
- IOSTAT, which reports disk and CPU usage.
- BUFSTAT, which displays the status of the I/O buffer cache.
- MEMSTAT, which prints a map of all the memory usage of the system.

Hardware Configuration Depends on Your Application Needs.

V7M-11 requires a minimum hardware configuration consisting of a processor, clock, memory, disk, and in most cases, a magtape. Magtape is recommended for file system backup and restore operations, receiving V7M-11 software updates, and information interchange with other V7M-11 users.

Cache memory is optional, as are disks, lineprinters, communication devices, and floating point processors. The kernel doesn't require or even use floating point. However, some system commands such as IOSTAT, accounting, and the debugger do. Your requirement for floating point hardware depends on the amount of floating point operations executed by your programs and the floating point performance requirements of those programs.


Ground & Sky Courier Network

Chapter 9

Interactive Application System (IAS)

IAS is a Proven Performer for a Variety of Applications.

Digital continues to support IAS, a mature operating system used extensively in business, defense, and other government operations. IAS offers multiuser timesharing and supports concurrent interactive, batch, and realtime applications. IAS includes the MACRO assembler (bundled). As options, FORTRAN IV, FORTRAN-77, SORT, CORAL 66, BASIC-11, and BASIC-PLUS-2 language processors can be added, as well as the RMS record and data base management facility. IAS features:

- A single, easy-to-learn and easy-to-use interactive command language
- Priority scheduling for realtime tasks
- Submission of batch jobs from interactive terminals
- Timesharing services for development of interactive applications programs
- A simple internal software interface for the development and use of special-purpose, multiuser interactive applications
- A sophisticated file system providing device independence; file protection; sequential, random, and relative file access; and, optionally, multikeyed ISAM
- System management facilities for system configuration, generation, and control
- Facilities to account for and restrict the use of system resources
- Dynamic allocation of system resources
- Use of shared, re-entrant code to minimize memory requirements

IAS supports a variety of peripherals useful in batch and realtime applications, including lineprinters, card readers, and laboratory peripherals.

As a batch system, IAS services multiple queues of batch jobs. FORTRAN, MACRO, and COBOL jobs can be submitted to batch. The user interface for batch processing is the same as the Program Development System (PDS) interactive interface. Therefore, programs can be developed in interactive mode and run in production in batch mode. The system manager controls the amount of service that batch jobs receive from the processor.

As a generalized, flexible base for executing interactive applications, IAS provides support for application-specific user interfaces for applications such as data entry, bank teller terminals, or engineering computation, where it is necessary or desirable to present a customized interface to terminal users (operators, for example).

Further, IAS supports the concurrent execution of multiple interactive applications. Thus, a data processing application and the program development system can execute concurrently and be serviced jointly by the timesharing facilities of the system.

The program development system, PDS, provides a computing environment that supports most application processing requirements of IAS users. As such, it presents to IAS terminal users a standard interface which requests and processes valid passwords and user names before making system facilities available. The interface allows the user to create programs, submit jobs to the batch stream, and issue commands to create and manipulate program and data files.

The interactive application facility is further enhanced by the capability of the FORTRAN IV-PLUS compiler and IAS to develop and support shareable programs. For the user, this means that system overhead (memory occupancy and swapping time) is minimized. Also, the user can allocate specific application interfaces and deallocate them as required. This facility is flexible and extendable. The system is easily modified and additional applications are easily added.

Special-purpose interfaces can be written and checked out using the IAS program development system and then installed by the system manager for use on specific terminals. IAS provides a number of system services that can be called from the application program to enhance the function of these special-purpose interfaces.

IAS provides the realtime processing facilities of multiprogramming, priority scheduling, power-fail restart, contingency exits, disk-based operation, and task checkpointing of realtime tasks. Realtime, interactive, and batch operations can occur concurrently and, normally, in that order of priority.

IAS system operations are managed by two executives. The realtime executive schedules realtime activities according to their priorities and manages the system resources not allocated to the timesharing activities. The timesharing executive schedules timesharing users on the basis of a time-slicing algorithm when realtime activities do not take precedence. Batch processing normally uses processor time available after interactive users are serviced. Both batch tasks and interactive tasks run under control of the timesharing scheduler.

The IAS System Monitor Provides System Flexibility.

The IAS operating system is controlled by a system monitor consisting of a realtime executive kernel and an optional timesharing scheduler. The primary functions of

the kernel include memory and disk management, supervision of privileged tasks (including realtime tasks and device handlers), file management, and maintenance of the general integrity of the system. The kernel maintains the Active Task List (ATL) to control task dispatching.

The timesharing scheduler (a sysgen option) controls both interactive and batch processing. It manages the execution of timesharing tasks by timeslicing and by swapping tasks into and out of memory.

Active Task List

The kernel coordinates the dispatching of all tasks on the system by scanning the entries in the Active Task List (ATL), a priority-ordered list of all resident active tasks in the system. Because of their requirement for immediate service, the I/O device-handler tasks are put at the top of the ATL. For the same reason, any user-designated realtime tasks are assigned to high-priority levels. the timesharing scheduler, which runs at a lower priority than I/O and realtime tasks, controls the scheduling of user timesharing tasks by inserting tasks in the ATL. Figure 5-1 illustrates the priority structure of the ATL.

Three "pseudo-tasks," called TSS1, TSS2, and TSSN, are used to control the dispatching of tasks. The timesharing scheduler - TSS1 - selects a task for execution by placing its entry in the ATL at a priority equal to itself. The scheduler then relinquishes control (for example, it waits for an event flag such as "time slice complete") to allow the kernel to dispatch to the user task. TSS2 is another pointer in the ATL.

TSSN is the null job: it runs continuously in a loop executing at priority 1, so that tasks below it on the ATL can never execute. When a timesharing task is not executing, TSS1 places the ATL entry for that task below that of TSSN.

Timesharing Scheduler

The objective of the scheduler is to reduce as far as possible the average response time to all user demands. In order to do so, it distinguishes between various levels of user importance and urgency of service. The scheduler maintains a number of queues, or levels, of tasks to be scheduled. It scans each level (high to low) in a round-robin fashion until it finds a memory-resident runnable task. (A non-resident ready-to-run task will cause the swapping system to be activated.)

A task which uses a full time quantum is transferred to the next lower level unless it is already at the lowest level. Tasks at lower levels are not scheduled as often as tasks at higher levels, but they are given a longer time quantum when next activated. The goal is that large jobs are run and swapped less frequently, but in compensation, receive more processor time once activated.

To prevent tasks from being starved of processor time because the scheduler is continuously scheduling higher priority tasks, a means of promoting tasks from one level to the level above is provided. If, over a given period of time, no scheduling

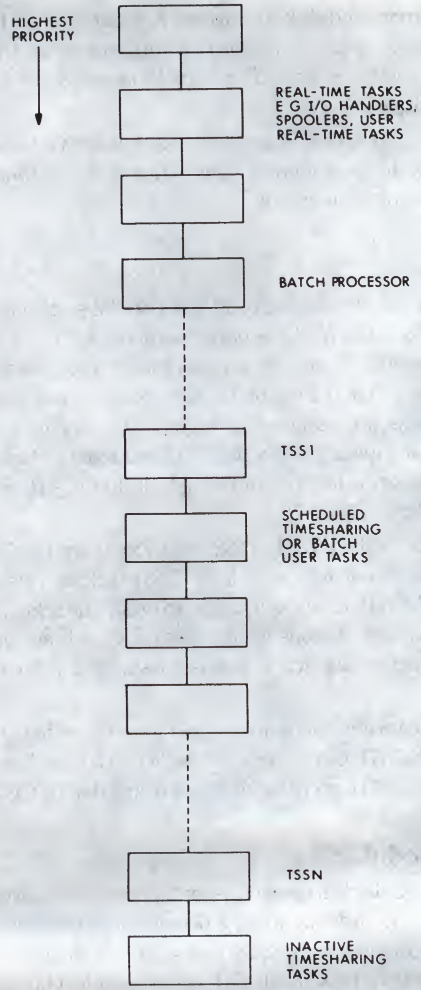


Figure 9-1 Schematic Diagram of ATL Structure

has been performed at a given level, then a task at that level is moved to the bottom of the level above.

The scheduler finds a runnable task that is not resident, then the task must be loaded (swapped) into memory to receive its quantum of CPU time. Space is created in memory by moving resident tasks to create the required contiguous space, and, if necessary, by writing inactive tasks to the swap area on disk(s).

Two time factors are associated with every task. The quantum determines the amount of CPU time a job may have before it is swapped out of main memory. The time slice is the maximum CPU time a task is allowed to use before a rescheduling operation is performed.

The time slice parameter can be adjusted to achieve the desired compromise between responsiveness and system throughput. If the time slice is set to its maximum value, all tasks will execute without interruption for their entire quantum. The time slice should never be smaller than the maximum quantum for a Level 1 task. All the parameters of the scheduling algorithm can be adjusted by the system manager to tailor IAS scheduling to the needs of the installation.

Batch Processing

Batch runs as if it were another timesharing terminal. The batch command language is the same as the general-purpose, interactive, program development command language, and it is processed by the same command language interpreter (see below).

Command input for the batch processor comes from a queue of commands. the batch queue itself is maintained independently, thus enabling jobs to be submitted at any time. The processor can service two types of queues. The system can maintain a spooled queue which consists of:

- Batch job files submitted from interactive terminals
- Command input from the card reader (if the card reader is designated as a spooled device)

Batch processing is initiated and terminated by the system manager, and the batch processor executes at the batch scheduling level, serviced by the timesharing scheduler. Though batch processing shares CPU time with interactive tasks, in timesharing systems its priority for service is always below that of the active tasks.

To assure that batch processing receives adequate service, the system manager can specify the percentage of CPU time to be made available to it, and the length of time (quantum) batch should run when it does receive service. For example, the system manager could direct IAS to devote ten percent of the available time to batch jobs in 2-second quanta.

Executive Data Structures

The IAS system maintains a number of common areas in which the various executive tasks store information and communicate with each other. SCOM contains the system tables, kernel node pool, lists, and some servicing routines. SYSRES, the System Resident Library, contains common routines which will be used by most tasks. IASCOM is a library containing timesharing nodes, lists, tables, and common

routines for manipulating the timesharing data structures. IASBIF is a buffer area used for communication between the timesharing control primitives, IASCOM, and the timesharing executive.

I/O Services and Device Independence

Input and output constitute a significant part of all programmed activity. Thus, IAS provides a variety of services to perform these operations.

The IAS file system is a collection of system services that permits the user to view I/O as a transaction between a program and a named, protected collection of records known as a file. The file system manages all data transfers and provides the mechanism whereby a file intended for a record-oriented device, such as a line-printer, can be dynamically directed to an area on magnetic storage.

Access to a user's files stored on a disk, DECtape, or labeled magnetic tape is controlled by a protection specification on each file. When creating a file, a user can specify whether other users may have access to the file and, if so, whether they may modify the file or merely read it.

One of the goals of any file system is to make the user program independent of the I/O hardware. Thus, while the storage characteristics of a medium are organized around physical records, the user deals only with logical records.

To provide greater device independence, the IAS user will in general use logical units instead of referring directly to physical devices. IAS provides a set of logical unit numbers (LUNs) which are not associated with specific physical devices or files until run time. In the source program, all device and file references use LUNs. These LUNs may be assigned to particular devices by a command issued before the program is executed.

Sharing of Common Routines

In a system designed to support many users, there is a high probability that many tasks will use the same code sequences, such as mathematical routines and specialized I/O routines.

The common code could be built directly into each task requiring it, but this might result in several copies of the same code occupying memory space at the same time. The alternative employed by IAS is to put the (shared) common code where all users can share it, so that only one copy of the code is required.

Under IAS, shared areas may be either data areas (global common), sets of common routines (libraries), or the pure (read-only) areas of complete tasks (shared tasks). Global common areas allow simultaneously active tasks to share data. A shareable library consists of routines which may be interrupted to service another request, then resume execution later at the point of interruption. (Users who write re-entrant routines can include their own shareable libraries in the IAS system.) Shared code does not need to be permanently resident; it can be loaded at the time a task which uses it is run. Programs written in either FORTRAN IV-PLUS or MACRO can be shared.

Command Language Interpreters Help You Communicate with Your System.

A command language interpreter (CLI) is a task which manages the interface between a person and the IAS system. PDS, for example, is the program development CLI supplied with IAS. It allows the general user to access all nonprivileged facilities of the system. Another CLI called the system control interface (SCI) helps the system operator alter the state of the system, to designate user interfaces (CLIs), and to allocate facilities to each other.

While PDS is the standard command language interpreter to which a general terminal is allocated, the system operator can designate a specific other task as the CLI for a terminal. For example, the operator might set aside one terminal to be used solely for program editing.

Users can write their own CLI tasks, which can be installed and allocated to timesharing terminals. Such user-written CLI tasks may define their own command language, which can be as simple and understandable as required, specifically designed for a particular application operation. Therefore, application terminal users do not have to learn a generalized command language such as PDS to perform their set of daily activities.

A CLI is written as a normal, nonprivileged task which can use, in addition to the standard system directives and file system facilities, the IAS system's timesharing control services. It can be written in any language which provides the facilities it requires; for example, a CLI that wishes to use the system QIO directive must be written in FORTRAN, MACRO, or BASIC (with user-defined functions).

The following two sections describe the two standard CLI tasks provided with the IAS system: PDS, the program development system, and SCI, the system control interface.

Program Development System (PDS)

A typical timesharing user interfaces with IAS through the program development system (PDS) command language interpreter. Under PDS, users can create, compile, link, load, and run programs. They can submit jobs to the batch stream, use various peripheral devices, and obtain system information.

PDS is a prompt-oriented system. After PDS is activated at a terminal, it invites the input of a command by issuing the prompt PDS. The user replies by typing a command name and its parameters, if any, followed by a carriage return. If a user does not supply all the parameters required in a command, the system will prompt for them. Additionally, the user can issue the HELP command to display the commands available.

The user can supply PDS commands in a file (called an "indirect file") rather than typing them in one at a time on the terminal. PDS processes the file in the same manner that it processes commands typed individually on the console. The

commands, as well as any error messages that occur during the execution of the commands, will be displayed on the user's output device.

There are several types of PDS commands: some that provide access or system information, some that allocate resources, some that manipulate files, and some that control task execution. The system manager can, when defining user accounts, designate certain PDS commands as privileged or nonprivileged for any particular users, by specifying which commands a user can issue. For example, some PDS commands control realtime task execution, and only those users who have been given appropriate privileges can issue them.

Except for the LOGIN, LOGOUT, JOB, and EOJ commands, all nonprivileged commands can be issued in either interactive or batch mode. When a command is issued in batch mode, it requires a dollar sign ($) preceding the first character of the command name.

In addition to the general PDS commands, IAS includes special PDS commands available only to the system manager, and only when he or she is logged in under the system management account. There are three types of privileged PDS system managements commands:

- Accounting commands to authorize users and report system use
- Realtime system control commands
- Volume and file control commands

System Control Interface (SCI)

System operators communicate with IAS through the system control interface (SCI) command language interpreter. The SCI command language uses the same syntax and conventions as the PDS command language, including prompting for missing parameters. Indirect SCI command files are also supported.

SCI commands enable an operator to monitor the system in four different areas:

Command language interpreter control

The command language interpreter (CLI) commands allow the operator to install and remove CLI tasks, allocate and deallocate resources (e.g., terminals) to a CLI task, and abort a CLI task at a particular terminal. These commands are used both to initialize a timesharing system and to modify the system's characteristics during system operation.

Overall system and task control

The system and task control commands enable the operator to: load and unload device handlers which are not permanently resident; mount and dismount volumes; set the system parameters to suit the current workload; and shut down the system. These commands also enable the operator to have ultimate task execution control. For example, the operator can terminate any task in the system. This can be useful when, for example, a batch task loops indefinitely because of internal errors.

Peripheral device control
Peripheral device control commands provide the operator with the facility to service user requests for access to disk packs, magnetic tapes or other removable media. Additionally, the operator can control the output spooling mechanism and the type of printer forms being used.

System information
The system information commands allow the system operator to display system information such as the active task list, CLI allocations, partition names and sizes, date and time, and device status.

SCI also allows all PDS commands.

IAS Also Provides Special Tasks and Utilities.

IAS provides a common command language for all standard system program development utilities such as the editor, linker and librarian.

In addition to the standard program development utilities, IAS also provides two special system tasks called VERIFY and BAD BLOCKS. These tasks are available only to the system manager. VERIFY is used to verify the consistency and validity of the files on a Files-11 volume. BAD BLOCKS is used to locate any unusable blocks on a disk and is normally run prior to disk volume initialization.

The system manager or operator also has available a special utility called CDA (Core Dump Analyzer), a task that executes on-line with other tasks to capture system information at the time of crash. It provides the capability to analyze the state of the system at the time the crash occurred.

General users have access to a special utility called PRESERVE. PRESERVE is a multiuser task that creates copies of disk, magnetic tape or DECtape volumes. PRESERVE can also be booted into memory as a stand-alone program. Other utilities, such as DSC (disk store/compress) and BRU (a backup utility), are explained in Chapter 17.

Chapter 10
Programming Languages

Programming Languages Make Your Computer Work for You.

Doing useful work on a computer depends upon the ease with which you can communicate your information and requests to it. Different circumstances determine different methods of programming, and broad categories of problems are often treated in different ways. This accounts for the growth of many different programming languages.

Some languages, such as FORTRAN, were originally intended for processing enormous amounts of numerical data through complicated formulas at high speeds. Others, such as COBOL, were developed for commercial applications in which there wasn't so much computing, but there was more data management. And still others, like BASIC, were invented to provide easy, nonthreatening access to students, so that they could quickly use the computer for problem solving, rather than worry about the intricacies of programming.

While some of these distinctions have become blurred over time, it is still true that certain kinds of problems are best attacked through certain kinds of languages, and the chapters that follow attempt to show the special strengths of each Digital-supplied language in satisfying specific application needs.

The American National Standards Institute (ANSI) defines standards for the various computer languages typically found in the United States. Such a standard is designated with a year suffix. FORTRAN-77, for example is the most recent FORTRAN standard; a programmer familiar with that language can tell immediately what general capabilities will be available in the language. Of course, computer languages are not frozen, and over time new standards develop either in industry or government, based upon need and pressure from users of the language. Consequently, most vendors offer standard languages with enhancements, so that they meet both government requirements and the needs of the programmers. Subsequent chapters explain Digital's enhancements to ANSI standards.

One of the great benefits of standardization is that each operating system takes care of the implementation of any particular language. For example, FORTRAN in the RSTS/E system might operate much differently from that in the RSX-11M system, but the programmer need not really know how those differences are managed. All that is needed to program with complete ease is to spend a day or two learning system-specific characteristics.

There are three types of language processors in programming. What they all do is take the words and symbols typed by the programmer at a terminal.and translate them into a series of binary codes that the computer can understand. When the computer is to output information, the processors take the binary codes and return them to a format that can be read and understood by people.

The first type of processor is called an *assembler*. It is a one-for-one translator; one coded instruction becomes one instruction to the computer. The assembler-level language on PDP-11 computers is called MACRO-11. It is slower to code and compile MACRO-11 programs than just about any other language, but in return the programmer gets considerably more control over the actual operation of a program than is possible under other languages.

Compilers and *interpreters* are the other two types of language processors. As opposed to the assembler-level language, these process what are always called the higher-level languages, the languages with such familiar names as FORTRAN, BASIC, and COBOL. In addition to such industry-wide languages, Digital-specific languages such as DATATRIEVE-11 and DIBOL-83 are also higher-level languages.

A fundamental difference between compilers and assemblers is the number of machine instructions that may be represented by a single language instruction. It may be, for example, that a single FORTRAN command is compiled into 20 or more machine instructions. Of course, this speeds up the coding process immensely, but it also means that the programmer must relinquish some of the control over program execution and environment that would be available to the MACRO-11 program.

Most compilers do not translate the *source code* that the programmer has written until they read the program all the way through at least once. Several passes over the source code are used to produce what is called *object code*, the form of binary formats that the machine can actually execute. Such multipass compilation allows the compiler to eliminate unnecessary code—called code optimization—and to perform many levels of error checking. A virtue of error checking at compilation time is that far fewer errors are actually encountered in the execution of the program. Thus, programmer time is more efficiently spent and computer resources are better used.

Interpreters translate source statements immediately into a format that the machine can interpret. The option for code optimization is lost, but this is balanced by the ability to execute programs on a statement-by-statement basis. Program development is enhanced in an interpreter, since there is an immediate response from the computer to the programmer in the case of detected errors. An entire program need not be read to find one level of error. In many situations, this is preferable to waiting until the entire program is compiled.

Most operating systems offered by Digital can support a variety of language processors. It is unlikely that a particular installation would require all the compilers and interpreters available from Digital, but it might have several, such as FORTRAN, DATATRIEVE, and BASIC. Language processors are usually layered prod-

ucts, purchased in addition to the operating system. For example, COBOL is a layered product for IAS, but BASIC is bundled with RSTS/E.

In many cases, application programs need not be written exclusively in a single language. For example, it may happen that a specific operation, such as the management of I/O devices (by I/O drivers) is best accomplished by programs written in assembler-level language, while the rest of the program is coded in COBOL. The driver may be coded in its most efficient format and later incorporated into the compiled COBOL object code. The complex details of this type of operation are handled by the operating system and the language processors, and are transparent to the programmer.

Many of the actual routines required by an application program are not written into the program. When the BASIC programmer asks the machine to extract a square root, for example, he might simply use the SQRT instruction in his program. Within the *Object Time System* (OTS) of the BASIC compiler is a mathematical functions library, which holds a square root algorithm. The SQRT instruction causes the algorithm to be called up into the program and to run on the appropriate variable. Since there are many cases in which it is simpler to include commonly used routines in programs than to rewrite them from scratch, each compiler is equipped with an Object Time System, filled with frequently required routines and functions. As the compilation process occurs, the locations of needed OTS routines are flagged. At the end of compilation, when the object code is ready, the appropriate routines from the OTS are inserted in the program at the flags. An interpreted language may also have an OTS, but it is more likely to be called at runtime, rather than at compile time.

You may insert your own common routines into the OTS, so that your efficiency in coding is improved. Drivers for your specific devices, or algorithms for often-run procedures, can be programmed once, and then just called as necessary.

Program development refers to the operation of writing and checking workable computer programs. Obviously, there is more to it than merely writing the language code, but the more sophisticated the operating system, the easier will be the use of the facilities available for program development. In computer jargon, the more features the operating system provides to simplify the programmer's task, the "friendlier" the program development environment. PDP-11 computers provide a very friendly environment under most operating systems. The history of software improvement is often the history of making the full capabilities of the computer more and more readily available to users.

Some of the facilities of the program development environment are listed and described below. Not every operating system provides all such facilities. The chart (Table 1-2, Chapter 1) provides a comparison across the operating systems provided for use with the PDP-11 family.

First among the program development utilities are the *editors*. An editor allows the addition, deletion, movement, and concatenation of text. It also provides capabilities for searching a text for specific character strings, for replacement of one

string by another, and for most of the other text manipulation operations one might want to perform in any writing. In developing a program, the editors provide an easy way to create a file and to correct and alter programs, either for experimenting with new ideas or for changing programs as required by new application circumstances or by the discovery of errors.

The *debugger* is another utility of extreme usefulness to programmers. It vastly simplifies the task of checking a program for logical errors by letting the programmer "step through" the program and follow what is happening to the values of chosen variables at each step of the way. Both the debugger and the editor are usually used by the programmer right at a video or hardcopy terminal, in an interactive session.

The *linker* is the crucial utility that takes object files written (created) by the language processors and prepares them for execution. It does this in various ways for various machines, operating systems, and languages. Basically, the linker adjusts addresses of the modules that make up the program—both those modules in the source code and those drawn from the OTS and its libraries; the linker "resolves" addresses—that is, it arranges the modules in such a way that there is no inconsistency in the references among modules and within the segments of the program. The linker also organizes, defines, and resolves certain kinds of symbols used internally in the compilation and execution of computer programs.

The *librarian* is, just as the name implies, the utility that manages the creation, modification, and maintainance of libraries in the operating system.

Modularity is the term used to describe the division of a program into blocks of logically related material. Very large programs might be modularized in order to compile efficiently, or to run efficiently. Complex programs might be broken into modules for program development: code optimization, debugging. An advantage of modularized programs in this latter situation is that modules can be computed individually before linking, so that an error requires only the recompilation of one module rather than the whole program.


RL02
RL02

Chapter 11

MACRO

MACRO-11—The Assembly-Level Language For PDP-11s.

PDP-11 MACRO (or MACRO-11) is a fast, compact assembly language that gives the programmer complete control over the environment in which a program is developed and executed. PDP-11 MACRO processes source programs written in the MACRO assembly language and produces a relocatable object module and optional assembly listing. MACRO is included with the RSX-11M-PLUS, RSX-11M, RSTS/E, RT-11, and IAS operating systems, as well as VAX/VMS.

PDP-11 MACRO provides for:

- Global symbols for linking separately assembled object programs. (This promotes modular program design.)
- Device and file name specifications for input and output files.
- User-defined macros.
- Comprehensive system macro library.
- Program sectioning directives.
- Conditional assembly directives.
- Assembly and listing control functions at program and command string levels.
- Alphabetized, formatted symbol table listing.
- Default error listing on command output device.

The MACRO assembler for all operating systems also features:

- Global arithmetic, global assignment operator, global label operator, and default global declarations.
- Multiple macro libraries with fast access structure.
- Predefined (default) register definitions.

MACRO Program Structure Processes Source Statements Sequentially.

A MACRO source program is composed of a sequence of source coding lines, each of which contains a single assembly language statement followed by a statement terminator, such as a carriage return. The assembler processes source statements sequentially, generating binary machine instructions and data words or performing assembly-time operations (such as macro expansions) for each statement.

A statement can contain up to four fields, identified by order of appearance and by specified terminating characters. The general statement is:

```
label:  operator  operand(s)  ;comments
```

of which the label and comment fields are optional. Operator and operand fields are interdependent: either can be be omitted depending on the contents of the other.

A label is a unique user-defined symbol that is assigned the value of the current location counter and entered into the user-defined symbol table. It provides a symbolic means of referring to a specific location within a program. The value of the label can be either absolute (fixed in memory independent of the position of the program) or relocatable (not fixed in memory), depending on whether the location counter value is currently absolute or relocatable.

Comments do not affect assembly processing or program execution, but are useful in source listings for later analysis, documentation, or debugging.

An operator field can contain a macro call, a PDP-11 instruction mnemonic, or an assembler directive. When the operator is a macro call, the assembler inserts the appropriate code during assembly to expand the macro; for an instruction mnemonic, it specifies the instruction to be generated and the action to be performed on any operands which follow; and when the operator is an assembler directive, it specifies a certain function or action to be performed during assembly. Operands can be expressions, numbers, symbolic arguments, or macro arguments.

Some statements have no operands:

```
BPT
```

Some statements have one operand:

```
CLR  R0
```

while others have two:

```
MOV  #344,R2
```

Symbols and Symbol Definitions

Three types of symbols can be defined for use within MACRO source programs: permanent symbols, user-defined symbols, and macro symbols. Correspondingly, MACRO maintains three types of symbol tables: the Permanent Symbol Table (PST), the User Symbol Table (UST), and the Macro Symbol Table (MST).

Permanent symbols consist of the PDP-11 instruction mnemonics and assembler directives. Also, the assembler has REGISTER names predefined for R0 to R5, SP (stack pointer), and PC (program counter). The PST contains all the permanent symbols automatically recognized by MACRO; it is part of the assembler itself. Since these symbols are permanent, they do not have to be defined by the user in the source program.

User-defined symbols are those given as labels or defined by direct assignment, while macro symbols are those symbols used as macro names. The UST and MST are constructed during assembly by adding the symbols to the UST or MST as they are encountered. To determine the value of the symbol, the assembler searches the three symbol tables; for opcodes, the search order is MST, PST, UST; for operands, the search order is UST, PST.

The search orders allow redefinition of Permanent Symbol Table entries as user-defined or macro symbols, so that the same name can be assigned to both a macro and a label.

User-defined symbols are either *internal* or *external* (global) to a source program module. An internal symbol definition is limited to the module in which it appears. A global symbol can be defined in one source program module and referenced within another.

Internal symbols are temporary definitions, resolved by the assembler. Global symbols are preserved in the object module and are not resolved until the object modules are linked into an executable program. With some exceptions, all user-defined symbols are internal unless explicitly defined as global.

A direct assignment statement with the general format *symbol expression* associates a symbol with a value.

By using two equal signs instead of one, the symbol is declared a global symbol. *Expressions* are combinations of terms that are joined together by binary operators— +, -, *, ÷, & (logical AND), ! (logical OR)—and that reduce to a 16-bit value.

Local symbols are specially formatted internal symbols used as labels within a given range of source code, called a local symbol block. They have the form *n$*, where n is a decimal integer between 1 and 65,535, inclusive, for example, 1$, 27$, 59$, 104$.

Local symbols provide a convenient means of generating labels to be referenced only within a local symbol block. Their use reduces the possibility of entry point symbols with multiple definitions. Because a local symbol may not be referenced from other source program modules or even from outside its local symbol block, local symbols of the same name can appear in other local symbol blocks without conflict.

Directives

A program statement can contain one of three different operators: a macro call, a PDP-11 instruction mnemonic, or an assembler directive. MACRO includes directives for:

- Listing control
- Function specification
- Data storage
- Radix and numeric usage declarations
- Location counter control
- Program termination
- Program boundaries information
- Program sectioning
- Conditional assembly
- Macro definition
- Macro deletion
- Macro attributes
- Macro message control
- Repeat block definition
- Macro libraries
- File control
- Symbol control

The sections that follow illustrate some of the capabilities of the various classes of directives.

Listing Control Directives

Several directives are provided to control the content, format, and pagination of all listing output generated during assembly. Facilities also exist for creating object module names and other identification information in the listing output.

The listing control options can also be specified at assembly time through options included in the listing file specification in the command string issued to the MACRO assembler. The use of these options overrides all corresponding listing control directives in the source program.

When no listing file is specified, any errors encountered in the source program are printed on the terminal from which MACRO was initiated.

Function Directives

Function control options are available through the .ENABL and .DSABL directives. These directives are included in a source program to invoke or inhibit certain MACRO functions and operations incidental to the assembly process. They include:

- Produce absolute binary output.
- Assemble all relative addresses as absolute addresses. This function is useful during the debugging phase of program development.

- Cause source columns 73 and greater (to the end of the line) to be treated as comment. The most common use of this feature is to permit sequence numbers in card columns 73-80.
- Truncate or round floating point literals.
- Accept lower case ASCII input instead of converting it to upper case.
- Enable a local symbol block to cross program section boundaries.
- Inhibit binary output.
- Inhibit the normal default register definitions.
- Treat all undefined symbol references as default global references.

Conditional Assembly Directives

Conditional assembly directives enable the programmer to include or exclude blocks of source code during the assembly process, based on the evaluation of stated condition tests within the body of the program. This allows a programmer to generate several variations of a program from the same source.

The programmer can define a conditional assembly block of code, and within that block, issue subconditional directives. Subconditional directives indicate:

- The assembly of an alternate body of code when the condition of the block tests false.
- The assembly of a non-contiguous body of code within the conditional assembly block, depending on the result of the conditional test on entering the block.
- The unconditional assembly of a body of code within a conditional assembly block.

Conditional assembly directives can be nested to 16 levels.

Macro Definitions and Repeat Blocks

In assembly language programming, it is often convenient and desirable to generate a recurring coding sequence by invoking a single statement within the program. In order to do this, the desired coding sequence is first established with dummy arguments as a macro definition. Once a macro has been defined, a single statement calling the macro by name with a list of real arguments (replacing the corresponding dummy arguments in the macro definition) generates the desired coding sequence or macro expansion.

MACRO can automatically create unique local symbols. This automatic facility is invoked on each call of a macro whose definition contains a dummy argument preceded by the question mark (?) character, if a real argument of the macro call is either null or missing.

An indefinite repeat block is a structure that is very similar to a macro definition. Such a structure is essentially a macro definition that has only one dummy argument. At each expansion of the indefinite repeat range, this dummy argument is replaced with successive elements of a specified real argument list. An indefinite repeat block directive and its associated repeat range are coded in-line within the

source program. This type of macro definition does not require calling the macro by name.

An indefinite repeat block can appear within or outside of another macro definition, indefinite repeat block, or repeat block.

Macro Calls and Structured Macro Libraries

All macro definitions must occur prior to their references within the user program. MACRO provides a selection mechanism for the programmer to indicate in advance those system macro definitions required in the program. (System macros include the monitor programmed requests or executive directives available with each operating system.)

The .MCALL directive is used to specify the names of all the macro definitions not defined in the current program but used in the program. When this directive is encountered, MACRO searches the system macro library file to find the requested definition.

MACRO extends this macro call facility by enabling the programmer to retrieve macros from libraries of user-defined macros. The .MCALL directive provides the means to access both user-defined and system macro libraries during assembly.

The MACRO assembler assumes that the system macro library and user-defined macro libraries are constructed in a special direct-access format to retrieve macro definitions quickly. These structured macro libraries are created by the Librarian utility program.

Each library file contains an index of the macro definitions it contains. When an .MCALL directive is encountered in the source program, MACRO searches the user macro libraries for the named macro definitions, and, if necessary, continues the search with the system macro library. Because each macro library contains an index of all of its entries, MACRO searches only the index in each library to find where the macro definition is stored.

Macro libraries to be searched may be specified by both the initial MACRO-11 command line and by use of the .LIBRARY directive. The .MDELETE directive may be used to delete a macro once used. This conserves dynamic memory.

Program Sectioning Directives

The .PSECT directive is used to declare names for program sections and to establish certain program section attributes. These program section attributes are used when the program is linked into an executable load module or task.

A program can consist of an absolute program section, an unnamed relocatable program section, and up to 254 named relocatable or absolute program sections. Absolute program sections link the program with fixed memory locations such as interrupt vectors and the peripheral device register addresses, as well as to define values of constants.

The relocatable program sections are not fixed at an absolute address. Instead, symbols within a relocatable section are defined relative to the start of that section.

The programmer specifies the overall ordering of relocatable .PSECTS, but the task builder (or linker) resolves the final addresses of the .PSECTS according to their attributes.

By maintaining separate location counters for each program section, MACRO allows the user to create data structures that are not physically contiguous within the program, but which can be linked contiguously following assembly.

The programmer can save the current .PSECT context with a .SAVE directive, and later restore that context with a .RESTORE directive.

The .PSECT directive allows the user to exercise absolute control over the memory allocation of a program at task build time, since any program attributes established through this directive are passed to the Task Builder. For example, if a programmer is writing programs for a multiuser environment, a program section containing pure code (instructions only) or a program section containing impure code (data only) can be explicitly declared through the .PSECT directive. Furthermore, these program sections can be explicitly declared as read-only code, qualifying them for use as protected, reentrant programs. In addition, program sections exhibiting the global attribute can be explicitly allocated in a task's overlay structure by the user at task build time. The advantages gained through sectioning programs in this manner relate primarily to control of memory allocation, program modularity, and more effective partitioning of memory.

The .PSECT directive allows the user to define the following program section attributes:

- *Access*—Two types of access can be permitted to the program section: read-only or read/write. RSX-11M-PLUS and IAS support read-only access by setting hardware protection for the program section.
- *Contents*—A program section can contain either instructions or data. This attribute allows the Task Builder to differentiate global symbols that are program entry-point instructions from those that are data values.
- *Scope*—The scope of the program section can be global or local. In building single-segment programs, the scope of the program has no meaning, because the total memory allocation for the program will go into the root segment of the task. The global or local attribute is significant only in the case of overlays. If an object module contains a local program section, then the storage allocation for that module will occur within the segment in which the module resides. Many modules can reference this same program section, and the memory allocation for each module is either concatenated or overlaid within the segment, depending on the argument of the program section defining its allocation requirements (see below). If an object module contains a global program section, the memory area allocations to this program section are collected across segment boundaries, and the allocation of memory for that section will go into the segment nearest the root in which the first memory allocation to this program section appeared.

- *Relocatability*—A program section can be absolute or relocatable. When a program section is declared to be absolute, the program section requires no relocation. The program section is assembled and loaded, starting at absolute virtual address 0. When the program section is declared to be relocatable, the Task Builder calculates a relocation bias and adds to it all references within the program section.
- *Allocation Requirements*—The program section can be concatenated or overlaid. When concatenated, all memory allocations to the program section are to be concatenated with other references to this same program section in order to determine the total memory allocation requirements for this program section. When overlaid, all memory allocations to the program section are to be overlaid. Thus, the total allocation requirement for the program section is equal to the largest individual allocation request for this program section.

MACRO Accepts Source Data From Any Input Device.

The MACRO assembler can accept source data from any input device. The sources to be included in a single assembly are listed in the command string from left to right in the order of assembly. The last statement in the last source specified is normally the .END statement, but if the .END statement is not provided, it is assumed. Assembler output consists of the binary object file and an optional assembly listing followed by the symbol table listing and a cross reference listing.

MACRO is a two-pass assembler. During pass one, MACRO locates and reads all required macros from libraries, builds symbol tables and program section tables for the program, and performs a rudimentary assembly of each source statement. During pass two, MACRO completes the assembly, writes out an object file, and generates an assembly and symbol table listing for the program.

The object module MACRO produces must be processed by the operating system's linker utility program (called Linker or Task Builder) to create an executable program. The linker joins separately assembled object modules into a single load module (or task image). The linker fixes (makes absolute) the values of the external or relocatable symbols in the object module.

To enable the linker to fix the value of an expression, MACRO passes it certain directives and parameters. In the case of the relocatable expressions in the object module, the linker adds the base of the associated relocatable program section to the value of the relocatable expression provided by MACRO. In the case of external expression values, the linker determines the value of the external term in the expression (since the external expression must be defined in at least one of the other object modules being linked together) and then adds it to the absolute portion of the external expression, as provided by MACRO.

In summary, an executable program image can be constructed from one or more source modules, which can be assembled either separately or together. The

resultant object module(s) must be linked together using the linker utility. Figure 9-1 illustrates the processing steps required to produce an executable program from several sources stored as files.

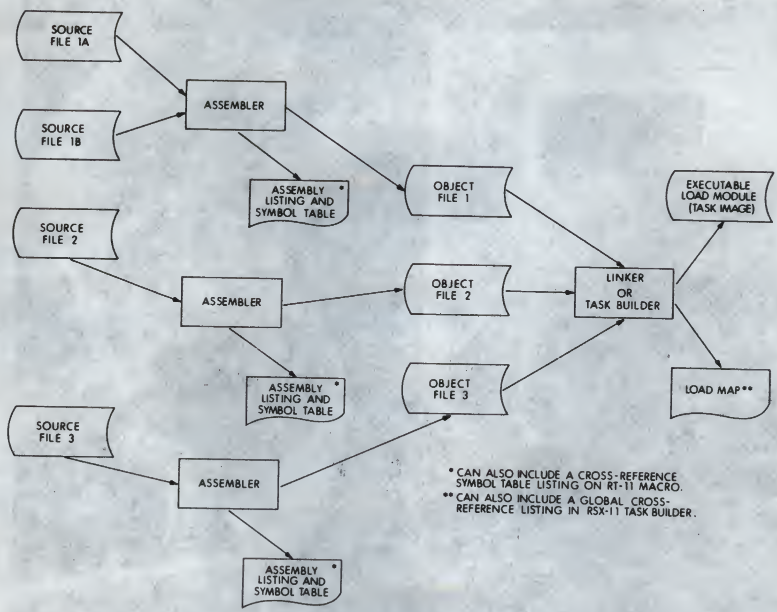
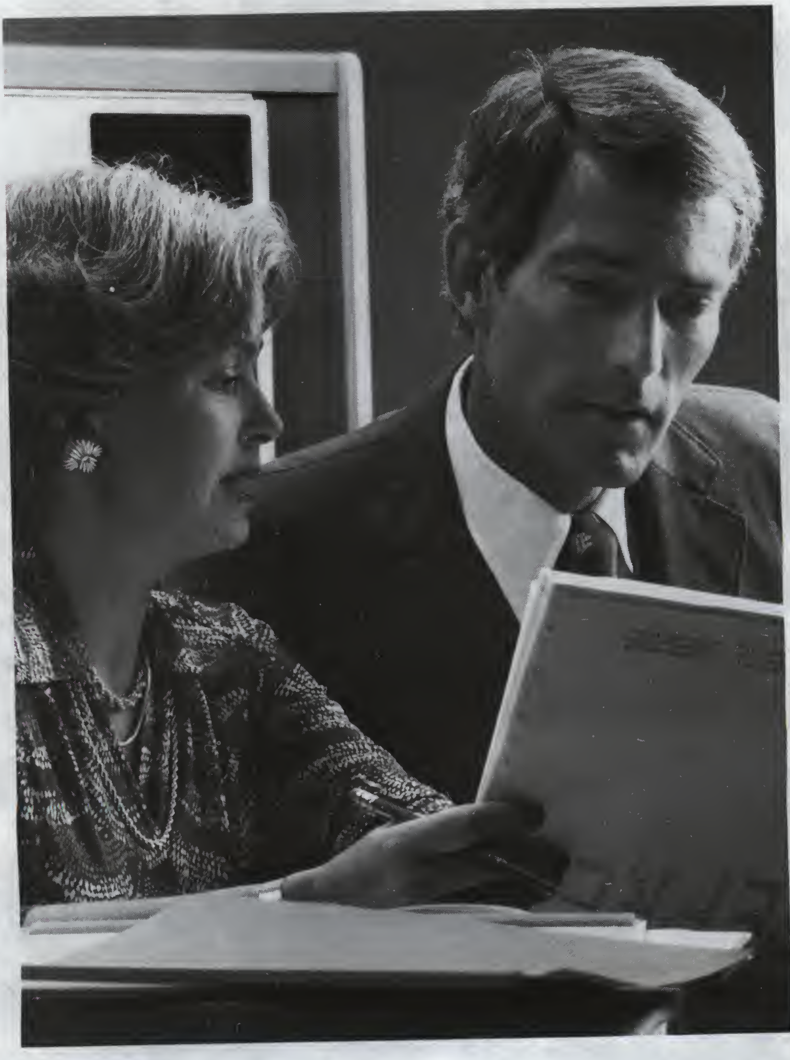


Figure 11-1 MACRO Assembly Procedure



Chapter 12

FORTRAN

FORTRAN Is Ideal for Manipulating and Performing Calculations of Numeric Data.

FORTRAN was developed in the mid-1950s specifically to handle scientific applications in which large amounts of computation were to be done. Since then, it has evolved into one of the most widely used languages, with applications in real-time control (scientific experiments, industrial processes, data collection and reduction), computation (structural analysis, simulation and modeling, electronic design, heavy computing data reduction), and general data processing (maintenance of databases and report generation). Because of its traditional predominance in certain markets and its long, stable history, FORTRAN continues to be taught to most people specializing in computer and information science in college.

Digital offers two versions of FORTRAN for use on its PDP-11 computers. The first, PDP-11 FORTRAN-77, conforms to the most recent ANSI FORTRAN standard, X3.9-1978 (commonly referred to as FORTRAN-77), at the subset language level. Earlier versions of PDP-11 FORTRAN-77 were called PDP-11 FORTRAN IV-PLUS and were based on the 1966 ANSI standard. PDP-11 FORTRAN-77 runs under the RSX-11M-PLUS, RSX-11M, and RSTS/E operating systems, as well as under VAX/VMS when used under the Applications Migration Executive (AME). It produces machine code highly optimized for execution on a PDP-11 with a floating point processor. PDP-11 FORTRAN-77 features optimization techniques, which improve memory efficiency and increase program execution speed.

The second FORTRAN offering, FORTRAN IV, is based on an earlier ANSI FORTRAN standard,(X3.9-1966). This FORTRAN language works on RSX-11M-PLUS, RSX-11-M, RT-11, and RSTS/E operating systems as well as on VAX/VMS under AME. FORTRAN IV is characterized by high compilation speed and efficiency in small memory environments.

The FORTRAN-77 Compiler Produces Optimized Machine Code.

The PDP-11 FORTRAN-77 compiler accepts a source program and produces a relocatable object module and optionally a listing file as output. PDP-11 FORTRAN-77 is designed to minimize the size and increase the speed of executable programs. It

accomplishes this through extensive optimizations such as subexpression elimination, peephole optimizations, removal of invariant expressions from DO loops, and allocation of processor registers across block IF constructs and DO loops.

The FORTRAN-77 compiler provides optional, switch-selectable support for programs conforming to the previous ANSI FORTRAN standard X3.9-1966. Programs that successfully compile using the PDP-11 FORTRAN-77 compiler can be compiled using VAX-11 FORTRAN without modification to the source code. Programs that successfully compile using PDP-11 FORTRAN-IV can be compiled using either FORTRAN-77 or VAX FORTRAN by setting the /NOF77 switch.

FORTRAN-77 Has Features From the Full-language.

PDP-11 FORTRAN-77 includes the following features of full-language FORTRAN as defined by the ANSI FORTRAN standard X3.9-1978:

- Double precision and complex data types.
- Function subprograms, including LEN, ICHAR, and INDEX.
- Exponentiation forms, including double precision.
- Format edit descriptors, including S, SP, SS, T, TL, and TR.
- Generic function selection based on argument data type for FORTRAN-defined functions.
- Use of any arithmetic expression as the initial value, increment, or final value in a DO statement.
- Use of a real or double-precision variable as a DO statement control variable.
- CLOSE and OPEN statements.
- Use of the specification ERR=s in READ or WRITE statements to transfer control when an error occurs to the statement specified by s.
- Use of list-directed I/O to perform formatted I/O without a format specification.
- Use of constants and expressions in the I/O lists of WRITE, REWRITE, TYPE, and PRINT statements.
- Specification of lower bounds for array dimensions in array declarators.
- Use of ENTRY statements in SUBROUTINE and FUNCTION subprograms to define multiple entry points.
- Use of PARAMETER statements to assign symbolic names to constant values.

Language Extensions Go Beyond the Standard.

The following language extensions beyond the ANSI FORTRAN standard X3.9-1978 are included in PDP-11 FORTRAN-77:

- You can use any arithmetic expression as an array subscript. If the expression is not an integer type, it is converted to integer type.

- Mixed-mode expressions can contain elements of any data type except character.
- The LOGICAL*1 and LOGICAL*2 data types have been added.
- The IMPLICIT statement redefines the implied data type of symbolic names.
- The following input/output statements have been added:

ACCEPT	
TYPE	Device-oriented I/O
PRINT	
READ (u'r)	
WRITE (u'r)	Unformatted direct-access I/O
FIND (u'r)	
READ (u'r,fmt)	
WRITE (u'r,fmt)	Formatted direct-access I/O
DEFINE FILE	File control and attribute specification
ENCODE	Formatted data conversion in memory
DECODE	
READ (u,f,key)	Indexed I/O
READ (u,key)	
REWRITE	Record control and update
DELETE	
UNLOCK	

- You can include any explanatory comment on the same line as any statement. These comments begin with an exclamation point (!).
- You can include debugging statements in a program by placing the letter D in column 1. These statements are compiled only when you specify a compiler command qualifier; otherwise, they are treated as comments.
- You can use any arithmetic expression as the control parameter in the computed GO TO statement.
- Virtual arrays provide large data areas outside of normal program address space.
- You can include the specification ERR=s in any OPEN, CLOSE, FIND, DELETE, UNLOCK, BACKSPACE, REWIND, or ENDFILE statement to transfer control to the statement specified by s when an error condition occurs.
- The INCLUDE statement incorporates FORTRAN statements from a separate file into a FORTRAN program during compilation.
- ENCODE and DECODE statements transfer data between variables or arrays in internal storage, and translate that data from internal to character form, or from character to internal form, according to format specifiers.

- The INTEGER*4 data type provides a sign bit and 31 data bits.
- You can use hexadecimal and octal constants in place of any numeric constants.
- O and Z format edit descriptors.
- You can use character substrings and all the character intrinsic functions defined in the full language except CHAR.

FORTRAN Programs Consist of Statements and Optional Comments.

Statements organize into program units, which are sequences of statements that define a computing procedure and terminate with an END statement. A program unit can be a main program or a subprogram. An executable program consists of one main program and one or more optional sub-programs.

Statements fall into two general classes: executable and nonexecutable. Executable statements specify the actions of a program; nonexecutable statements describe data arrangement and characteristics, and provide editing and data-conversion information as well.

Statements are also divided into physical sections called lines. A line is a string of up to 80 characters. If a statement is too long to fit on one line, it can be continued on additional lines, called continuation lines.

A label identifies a statement so other statements can transfer control to it or get the information it contains. The label is an integer placed in the first five columns of a statement's initial line. Any statement can have a label; however, only executable and FORMAT statements can be referenced with a label.

Comments don't affect program processing in any way; they are merely a documentation aid. Comments can describe the action of a program, identify program sections and processes, and help in reading the source program listings. Any printable character can appear in a comment.

The Object Time System Helps Build Tasks Ready For Execution.

The compiler's Object Time System (OTS) is a library of routines that are selectively linked with compiler-produced object modules by the operating system's task-builder, to produce a task ready for execution. The PDP-11 FORTRAN-77 OTS contains routines for I/O processing, task control, error processing, mathematical computation, and system subroutine access. By selective linking, if a program performs only sequential formatted I/O, none of the direct-access I/O routines is included in the task.

The OTS is composed of the following routines:

- Math routines, including the FORTRAN-77 library functions and other arithmetic routines (e.g., exponentiation routines).
- Miscellaneous utility routines (e.g. ASSIGN, DATE, ERRSET).
- Routines that handle FORTRAN-77 input/output.
- Error-handling routines that process arithmetic errors, I/O errors, and system errors.
- Miscellaneous routines required by the compiled code.

PDP-11 FORTRAN-77 is distributed with both of the following object time systems.

- The OTS based on File Control Services (FCS) is a package of routines that can handle many file operations transparently to the user, and allows sequential and random access to sequentially organized files.
- The OTS based on Record Management Services (RMS) uses RMS to provide access to sequential, relative, and indexed files.

FORTRAN-77 Optimizations Increase Execution Efficiency.

Optimizations are techniques used to increase the execution efficiency of an object program. PDP-11 FORTRAN-77 optimizations include:

- Peephole optimizations: The initial machine instructions generated by a FORTRAN program are examined to find operations that can be replaced by shorter, faster code sequences. The final code generated by the compiler contains these improved code sequences.
- Common subexpression elimination: Often the same subexpression appears in more than one computation. If the values of the operands of a common subexpression are not changed between computations, that value can be computed once and substituted wherever the subexpression appears.
- Removal of invariant expressions from DO loops: An algorithm executes faster if computations are moved from frequently executed program sequences to less frequently executed program sequences. In particular, computations within a loop involving only constants can be moved outside the loop.
- Allocation of processor registers across block IF constructs and DO loops: Wherever possible, frequently referenced variables are retained in registers to reduce the number of load and store instructions executed. Frequently used variables and expressions are also assigned to registers across block IF constructs and DO loops.
- Sharable Code: For the RSX-11M-PLUS operating system, the compiler produces shared object code as a compile-time option. Shared tasks may then be created by using the multiuser-linker option. This improves memory utilization in multiuser systems because many users share one memory-resident task.

FORTRAN Offers a Choice of Debugging Tools.

FORTRAN-77 DEBUG is a symbolic debugger available with FORTRAN-77. In addition, there are two standard debugging facilities available to both FORTRAN-77 *and* FORTRAN IV programmers.

The *FORTRAN Object Time System* provides a traceback feature for fatal run-time errors. This feature locates the actual program unit and line number of a run-time error. Immediately following the error message, the error handler will list the line number and program unit name in which the error occurred. If the program unit is a subroutine or function subprogram, the error handler will trace back to the calling program unit and display the name of that program unit and the line number where the call occurred. This process will continue until the calling sequence has been traced back to a specific line number in the main program. This allows the exact determination of the location of an error even if the error occurs in a deeply nested subroutine.

In addition to the FORTRAN OTS error diagnostics that include the traceback feature, there is another debugging tool available. A "D" in column one of a FORTRAN statement allows that statement to be conditionally compiled. These statements are considered comment lines by the compiler unless the appropriate debugging lines switch is issued in the compiler command string. In this case, the lines are compiled as regular FORTRAN statements. Liberal use of the PAUSE statement and selective variable printing can provide the programmer with a method of monitoring program execution. This feature allows the inclusion of debugging aids that can be compiled in the early program testing stages and later eliminated without source program modification.

FORTRAN-77 DEBUG Helps You Find Errors.

PDP-11 FORTRAN-77 DEBUG is a symbolic debugger designed to help find logic and programming errors in a successfully compiled program that doesn't run correctly. The program may be terminating abnormally, giving incorrect output, or going into an infinite loop.

Abnormal termination of a program suggests either a logical error or an error caused by something in the environment. Since abnormal termination usually occurs reasonably soon after the error that caused it, a useful approach to locating the error is to examine the output of the program at points just before termination. This technique does not always work, however, when the error causes infinite looping or when a pointer error leads the program to an incorrect location. In these cases, forward tracing is the best method. The debugger can advance the program in predetermined steps, examining locations as it goes. When the debugger encounters the unexpected output, it can be used to isolate the area of code that caused it.

The PDP-11 FORTRAN-77 DEBUG is a powerful and flexible tool that helps find errors in a program. Among its features are:

- It is interactive. You issue debugger commands from your terminal and see their effects immediately.
- It is symbolic. You can refer to program locations by the symbols you used for them in your program. The debugger output uses symbols wherever possible.
- It understands variable names and data types and will accept and display data in a variety of formats.
- It gives online help. When you type HELP, the debugger responds with a list of commands and related features to help you debug.

FORTRAN-77 DEBUG commands include:

- file-spec
- CANCEL
- DEFINE
- DEPOSIT
- DISABLE
- ENABLE
- EVALUATE
- EXAMINE
- EXIT
- GO
- HELP
- SET
- SHOW
- STEP
- UNDEFINE

FORTRAN IV Optimizes Code and Simplifies Programming.

PDP-11 FORTRAN IV is based on the previous specification for ANSI FORTRAN, X3.9-1966. The following are enhancements in FORTRAN IV not found in this standard:

- Array Subscripts—Any arithmetic expression can be used as an array subscript. If the value of the expression is not an integer, it is converted to integer type.
- Array Dimensions—Arrays can have up to seven dimensions.
- Alphanumeric Literals—Strings of characters bounded by apostrophes can be used in place of Hollerith constants.
- Mixed-Mode Expressions—Mixed-mode expressions can contain any data type, including complex and byte.

- End of Line Comments—Any FORTRAN statement can be followed, in the same line, by a comment beginning with an exclamation point.
- Debugging Statements—Statements that are included in a program for debugging purposes can be so designated by the letter D in column 1. Those statements are compiled only when the associated compiler command string option switch is set. They are treated as comments otherwise.
- Read/Write End-of-File or Error Condition Transfer—The specifications END=n and ERR=n (where n is a statement number) can be included in any READ or WRITE statement to transfer control to the specified statement upon detection of an end-of-file or error condition. The ERR=n option is also permitted in the ENCODE and DECODE statements, allowing program control of data format errors.
- General Expressions in I/O Lists—General expressions are permitted in I/O lists of WRITE, TYPE, and PRINT statements.
- General Expression DO and GO TO Parameters—General expressions are permitted for the initial value, increment, and limit parameters in the DO statement, and as the control parameter in the computed GO TO statement.
- DO Increment Parameter—The value of the DO statement increment parameter can be negative.
- Optional Statement Label List—The statement label list in an assigned GO TO is optional.
- Override Field Width Specifications—Undersized input data fields can contain external field separators to override the FORMAT field width specifications for those fields (called "short field termination"), permitting free-format input from terminals.
- Default FORMAT Widths— Specifying input or output formatting by type and default width supplies precision values to the programmer.
- Additional I/O Statements:

File Control and Attribute Definition
    OPEN
    CLOSE
List-Directed (Free Format) u = Logical Unit Number
    READ (u,*)
    WRITE (u,*)
    TYPE*
    ACCEPT*
    PRINT*
Device-Oriented I/O
    ACCEPT
    TYPE
    PRINT

Memory-to-Memory Formatting
  ENCODE
  DECODE
Unformatted Direct Access I/O
  DEFINE FILE
  READ (u'r)   u = logical unit number
  WRITE (u'r)   r = record number
  FIND (u'r)

The unformatted direct access I/O facility allows the FORTRAN programmer to read and write files written in any format.

- Logical Operations on INTEGER Data—The logical operators .AND., .OR., .NOT., .XOR., and .EQV. may be applied to integer data to perform bit masking and manipulation.
- Additional Data Type—The byte data type (keyword LOGICAL*1 or BYTE) is useful for storing small integer values as well as for storing and manipulating character information.
- IMPLICIT Declaration—IMPLICIT redefines the implied data type of symbolic names.

A Fast Compiler Allows Tradeoffs.

The PDP-11 FORTRAN IV compiler and Object Time System are available as an optional language processing system on the RSX-11M-PLUS, RSX-11M, RSTS/E, and RT-11 operating systems, as well as on VAX/VMS under AME. The compiler accepts source programs written in the FORTRAN IV language and produces an object file that must be linked prior to execution.

A fast, one-pass compiler, the FORTRAN IV compiler has options that allow program size (threaded code) versus execution speed (in-line code) tradeoffs. FORTRAN IV compiler optimizations include:

- Common subexpression elimination
- Local code tailoring
- Array vectoring
- Optional in-line code generation for integer and logical operations

Despite its small size requirements and high compilation rate, FORTRAN IV provides a high level of automatic object program optimization. The compiler performs redundant expression elimination, constant expression folding, branch structure optimization, and several types of subscripting optimizations.

FORTRAN IV has no statement-ordering requirements; therefore, declarations can appear anywhere within the source program. Terminal format input (using the tab character to delimit field) makes program preparation easier.

In order to allow larger FORTRAN programs, FORTRAN IV can allocate array storage outside a program's logical address space. Such arrays are called virtual

arrays and can contain any data type, but they may also require operating system support of memory management directives.

An Object Time System Contains Common Sequences of Machine Instructions.

A few executable FORTRAN statements can be translated directly into machine instructions. Typical FORTRAN operations, however, require long sequences of PDP-11 machine instructions. Standard sequences, for example, are needed to locate an element of a multidimensional array, initialize an I/O operation, or simulate a floating point operation not supported by the hardware configuration.

The common sequences of PDP-11 machine instructions are contained in the Object Time System (OTS) library. The FORTRAN IV compiler does not always generate pure machine instructions for the FORTRAN source code statements. When using the threaded code option, it simply determines which combination of appropriate OTS routines is needed to implement a FORTRAN program. During the linking process for an object program, the linker utility includes the needed OTS routines into the load module. During program execution, these routines are chained together to effect the desired result. However, in-line code is used for improved execution speed for some operations where appropriate.

During compilation, FORTRAN IV performs ten categories of program optimization.

Briefly, they are:

- Compiled FORMAT Statements—FORMAT statements are translated into internal form at compile time, increasing execution speed and decreasing program size.
- Array Vectoring—Provides for faster location of array elements in multidimensional arrays.
- Constant Folding—Integer constant expressions are evaluated at compile time.
- Constant Subscript Evaluation—Constant subscript expressions in array calculations are evaluated at compile time.
- Unreachable Code Elimination—Unreachable statements are eliminated from the object code.
- Common Subexpression Elimination—Redundant subexpressions whose operands do not change between computations are replaced by temporary values calculated only once.
- Peephole Optimizations—Sequences of operations are replaced with shorter and faster equivalent operations.
- Branch Optimization for Arithmetic and Logical IF—Branch structures can be sped up and decreased in size.
- Register Allocation—Register allocation is improved to minimize direct memory references for variables.

- Loop Optimization—Expressions dependent on loop index variables are replaced with less complex arithmetic operations.

The Compiler Works Fast Without Temporary Files.

Instead of using temporary files to process source programs, the FORTRAN IV compiler performs all its activities in main memory. It reads the entire source program once, stores it in memory in a compacted format, and processes the compacted code in memory. Since a disk device is not used for temporary file operations, compilation speed is significantly increased.

To reduce the memory requirements of such a compilation system, the FORTRAN IV compiler employs a multiphase overlaid structure. The compiler consists of a large number of overlays. Most of the space allocated to the compiler is occupied by the compressed source code.

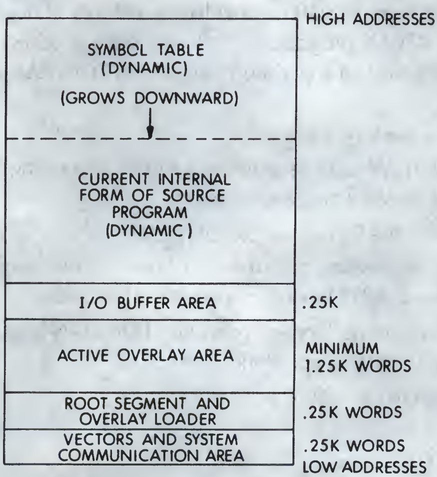


Figure 12-1 Compile-Time Memory Map

The compiler begins by reading in as much of the source program as can fit in memory. It then compresses the source code in memory by removing blanks and other unnecessary data. It continues to read in more source code, compressing it as it goes, until the entire program segment fits in memory.

Once the source code is compressed into memory, the compiler begins processing the internal form of the source code as a whole. Because the entire program segment is available to the compiler, FORTRAN IV does not require statement ordering restrictions.

FORTRAN IV Works Across a Spectrum of Operating Systems.

Though the compiler operation and facilities under all operating systems are essentially identical, each operating system provides additional features particular to the environment. The monitor programmed requests or executive directives, for example, are usually available as a library of FORTRAN-callable routines.

Under RT-11

The entire PDP-11 FORTRAN IV language processing system is operational in 16 Kbytes under the RT-11 SJ, FB, or XM monitors. To support strings, 32 Kbytes are required.

The RT-11 System Subroutine Library (SYSLIB) is a collection of FORTRAN-callable routines that allow a FORTRAN user to utilize various features of the RT-11 Foreground/Background (FB) and Single-Job (SJ) monitors. SYSLIB also provides various utility functions, a complete character string manipulation package, and two-word integer support. SYSLIB is provided as a library of object modules to be combined with FORTRAN programs at link-time. SYSLIB allows the RT-11 FORTRAN user to write almost all application programs in FORTRAN with no assembly language coding.

Also available under RT-11 are:

- A library of FORTRAN-callable graphics routines supporting the VT11, GT40, GT42, and GT44 graphics hardware systems.
- Plotting support for the LV11 electrostatic printer/plotter
- Laboratory data acquisition and manipulation routines used in conjunction with the LPS-11 and AR11 laboratory peripheral hardware.
- The Scientific Subroutine Library, providing FORTRAN-language routines for mathematical and statistical applications.
- Stand-alone program execution.

Under RSTS/E

PDP-11 FORTRAN IV operates in interactive or batch mode under the RSTS/E monitor. The FORTRAN IV language processing system includes the FORTRAN IV compiler, the Object Time System (OTS), and several utility programs.

The entire system (including compiler and optimization components) is completely functional in a 16-Kbyte user area. A system interface occupying eight Kbytes of memory is shareable among all FORTRAN IV users on the system. In addition, the FORTRAN IV system provides overlay support for programs and data, allowing extremely large programs to be run in a small region of memory.

RSTS/E FORTRAN IV provides assembly language subprogram support, using the MACRO assembler. Although the assembly language subprogram cannot issue

any monitor calls, MACRO provides the experienced user with a tool to further enhance computational performance.

Under RSX-11

In RSX-11M and RSX-11M-PLUS, the FORTRAN IV compiler runs in a minimum partition of 14 Kbytes. If run in a larger partition, it uses the extra space for program and symbol table storage.

An RSX-11 library consists of object modules. Two types of libraries exist, shared and relocatable.

Relocatable libraries are stored in files. Object modules from relocatable libraries are built into the task image of each task referencing the module. The Task Builder is used to include modules from relocatable libraries in a task image. When a library specification is encountered in the command string, those modules in the library that contain definitions of any currently undefined global symbols are included in the task image. The user can construct relocatable libraries of assembly language and FORTRAN routines using the Librarian utility.

Shared libraries are located in main memory and a single copy of each library is used by all referencing tasks. Access to a shared library is gained by specifying the name of the library in an option at taskbuild time. Shared libraries are built using the taskbuilder. They must contain shareable (reentrant) code.

Each RSX-11 system has a system relocatable library. The system relocatable library is automatically searched by the Task Builder if any undefined global references are left after processing all user-specified input files. The FORTRAN OTS may be included in the system library and hence is loaded automatically with FORTRAN programs.

The RSX-11 system library provides FORTRAN-callable forms of most executive directives. The FORTRAN programmer can schedule the execution of tasks, communicate with concurrently executing tasks, and manipulate system resources through these calls.

Industrial Society of America (ISA) extensions for process I/O control are available in FORTRAN-callable format under RSX-11M. Support for laboratory and process control peripherals is also included.

Libraries Contain Functions and Routines.

Both the FORTRAN-77 programmer and the FORTRAN IV programmer can create a library of commonly used assembly language and FORTRAN functions and subroutines. The operating system's librarian utility provides a library creation and modification capability. Library files can be included in the command string to the linker utility. The linker recognizes the file as a library file and links only those routines in the library that are required in the executable program. By default, the linker also automatically searches the FORTRAN system library for any other required routines.

Table 11-1 PDP-11 FORTRAN-77 and PDP-11 FORTRAN IV Common Language Components

Expression Operators

Type	Operator	Operates On
Arithmetic	** exponentiation * multiplication / division +,-addition, subtraction, unary plus and minus	arithmetic or logical constants, variables and expressions
Relational	.GT. greater than .GE. greater than or equal to .LT. less than .LE. less than or equal to .EQ. equal to .NE. not equal to (FORTRAN-77) .NQ. not equal to (FORTRAN IV)	arithmetic or logical constants, variables and expressions (all relational operators have equal priority)
Logical	.NOT. .NOT.A is true if and only if A is false .AND. A.AND.B is true if and only if A and B are both true .OR. A.OR.B is true if and only if A or B or both are true .EQV. A.EQV.B is true if and only if either A and B are both true or A and B are both false .XOR. A.XOR.B is true if and only if A is true and B is false or B is true and A is false	logical or integer constants, variables and expressions

.EQU. and .XOR. have equal priority.

.NEQU. is the same as .XOR. (On FORTRAN-77)

Assignment Statements

variable=expression	Arithmetic/Logical Assignment: The value of the arithmetic or logical expression is assigned to the variable.

ASSIGN-TO	The ASSIGN statement is used to associate a statement label with an integer variable. The variable can then be used as a transfer destination in a subsequent assigned GO TO statement in the same program unit.

Control Statements

GO TO	Unconditional	Transfers control to the same statement every time it is executed.
	Computed	Permits a choice of transfer destinations, based on a value of an expression within the statement.
	Assigned	Transfers control to a statement label that is represented by a variable. Because the relationship between the variable and a specific statement label must be established by an ASSIGN statement, the transfer destination can be changed, depending upon which ASSIGN statement was most recently executed.
IF	Arithmetic	Transfers control to a statement depending on the value of an arithmetic expression. Used for conditional control transfers.
	Logical	Executes a statement if the test of a logical expression is true.
	Block	Conditionally executes blocks (or groups) of statements (FORTRAN-77 only).

DO	Causes the statements in its range to be repeatedly executed a specified number of times. The range of the DO begins with the statement following the DO and ends with a specified terminal statement. The number of iterations is determined by the values for the initial, terminal, and increment parameters.
CONTINUE	Passes control to the next executable statement. Used primarily as the terminal statement of a DO loop when that loop would otherwise end with a GO TO, arithmetic IF, or other prohibited control statement.
CALL	Executes a SUBROUTINE, subprogram, or other external procedure and passes it actual arguments to replace the dummy arguments in the subprogram.
RETURN	Returns control from a subprogram to the calling program unit.
PAUSE	Temporarily suspends execution and displays a message on the terminal.
STOP	Terminates program execution and returns control to the operating system. Prints an optional message on the terminal.

END	Marks the end of a program unit. In a main program, if control reaches the END statement, a CALL EXIT is implicitly executed. In a subprogram, a RETURN statement is implicitly executed.
OPEN	Associates an existing file with a logical unit, or creates a new file and associates it with a logical unit. In addition, the statement can contain specifications for file attributes that direct the creation or subsequent processing. The attributes include specifying: the file name, the method of access (direct, sequential or append), protection (read-only or read/write), form (formatted, unformatted), record size, block allocation or extension, whether the file can be shared, and disposition (whether the file is to be deleted or saved when closed). In addition, the OPEN statement can be modified by an ERR keyword that specifies the statement to which control is transferred if an error is detected.
CLOSE	Disassociates a file from a logical unit. Disposition attributes specified in the OPEN statement can be modified. For example, a file opened as a file to be deleted can be saved, or a file opened to be saved can be deleted.

Input/Output Statements

READ	Formatted	Reads at least one logical record from the specified unit according to the given format specifications, and assigns values to the elements in a list.
	Unformatted	Reads one logical record from the specified unit, assigning the input values to the variables in a list.
	Direct Access	Reads the specified logical record from the specified unit and assigns the input values to the variables in a list.
	List-directed	Reads data from the specified unit, converts it into internal format, and assigns the input values to the elements of the I/O list, converting the value to the data type of the element if necessary.
	Error Control	Optional elements in the READ statement allow control transfer on error conditions. If an end-of-file condition is detected and the END option is specified, execution continues at a given statement. If a recoverable I/O error occurs and the ERR option is specified, execution continues at a given statement.
WRITE	Formatted	Writes one or more logical records containing the values of the variables in a list onto the specified unit in the given format.

	Unformatted	Writes one logical record containing the values of the variables in the list onto the specified unit.
	Direct Access	Writes one logical record containing the values of the variables in the list into the specified record of the given unit.
	List-directed	Writes the elements of the I/O list to the specified unit, translating and editing each value according to the data type of the value.
	Error Control	Optional elements in the WRITE statement allow control transfer on error conditions. If an I/O error occurs and the ERR option is specified, execution continues at the given statement.

ACCEPT	Identical to a formatted or list-directed READ statement, except that input comes from a logical unit normally connected to the terminal keyboard.
TYPE	Identical to a formatted or list-directed WRITE except that output is directed to a logical unit normally connected to the terminal printer.
PRINT	Same as a TYPE statement, except that output is directed to a logical unit normally connected to the lineprinter.
DEFINE FILE	Defines the record structure of a direct access file: the logical unit number, the number of fixed-length records in the file, the length of a single record, and the pointer to the next record.
REWIND	The given logical unit is repositioned to the beginning of the currently open file.
BACKSPACE	The currently open file on the given logical unit is backspaced one record.
END FILE	An end-of-file record is written on the file open on the given logical unit.
FIND	Positions the direct access file on the given logical unit to the specified record and sets the associated variable.
ENCODE	Writes the elements in the I/O list into a memory buffer, translating the data into ASCII format. The ERR option allows control transfer to a given statement if an error condition is detected.
DECODE	Reads the elements in the I/O list from a memory buffer, translating the data from ASCII format into internal binary format. The ERR option allows control transfer to a given statement if an error is detected.

Format Statements

FORMAT	Describes the format in which one or more records are to be transmitted. The format descriptors include integer and octal, logical, real, double precision, complex, literal and editing. Real, double precision, and complex formats can be scaled.

Specification Statements

IMPLICIT	Overrides the implied data type of symbolic names, in which all names that begin with the letters I, J, K, L, M, or N are presumed to be INTEGER values, and all names beginning with any another letter are assumed to be REAL values, unless otherwise specified. IMPLICIT allows the programmer to define the initial letters for implied data types. If a variable is not given an explicit type, and its name begins with a letter defined in an IMPLICIT statement, its default type is that defined by the IMPLICIT statement.
type var1, var2,...,varn	Type Declaration: The given variable names are assigned the specified data type in the program unit. Type is one of INTEGER*2, INTEGER*4, REAL*4, REAL*8, DOUBLE PRECISION, COMPLEX*8, LOGICAL*4, LOGICAL*1, or BYTE.
DIMENSION	Specifies the number of dimensions in an array and the number of elements in each dimension.
COMMON	Reserves one or more contiguous blocks of storage space under the specified name to contain the variables associated with the block name.
VIRTUAL	Reserves space for one or more arrays to be located outside normal program storage.
EQUIVALENCE	Declares two or more variable names in the same program unit to be associated with the same storage location.
SAVE	Retains the definition status of an entity after execution of a RETURN statement in a subprogram.
EXTERNAL	Permits the use of external procedures (functions, subroutines, and FORTRAN library functions) as arguments to other subprograms.
INTRINSIC	Declares one or more symbolic names to be FORTRAN intrinsic functions.
DATA	Assigns initial values to variables, arrays, and array elements prior to program execution.
PARAMETER	Assigns a symbolic name to a constant value.
PROGRAM	Assigns a symbolic name to a main program unit. If present, it is the first statement in the main program.
BLOCK DATA	Begins a special type of program unit that declares common blocks and defines data in common blocks.

User-Written Subprograms

name (var1, var2,...) = expression	Arithmetic Statement Function: Creates a user-defined function having the variables as dummy arguments. When referenced, the expression is evaluated using the actual arguments in the function call.
FUNCTION	Begins a FUNCTION subprogram, indicating the program name and any dummy variable names. An optional type specification can be included.
SUBROUTINE	Begins a SUBROUTINE subprogram, indicating the program name and any dummy variable names.

FORTRAN Library Functions

ABS(X)	Real absolute value
IABS(X)	Integer absolute value
DABS(X)	Double Precision absolute value
CABS(Z)	Complex to Real, absolute value
FLOAT(I)	Integer to Real conversion
IFIX(X)	Real to Integer conversion
SNGL(X)	Double to Real conversion
DBLE(X)	Real to Double conversion
REAL(Z)	Complex to Real conversion
AIMAG(Z)	Complex to Real conversion
CMPLX(X,Y)	Real to Complex conversion
AINT(X)	Real to Real truncation
INT(X)	Real to Integer conversion
IDINT(X)	Double to Integer conversion
AMOD(X,Y)	Real remainder
MOD(I,J)	Integer remainder
DMOD(I,J)	Double Precision remainder
AMAX0(I,J,...)	Real maximum from Integer list
AMAX1(X,Y,...)	Real maximum from Real list
MAX0(I,J,...)	Integer maximum from Integer list
MAX1(X,Y,...)	Integer maximum from Real list
DMAX1(X,Y,...)	Double maximum from Double list
AMIN0(I,J,...)	Real minimum of Integer list
AMIN1(X,Y,...)	Real minimum of Real list

MIN0(I,J,...)	Integer minimum of Integer list
MIN1(X,Y,...)	Integer minimum of Real list
DMIN1(X,Y,...)	Double minimum from Double list
SIGN(X,Y)	Real transfer of sign
ISIGN(I,J)	Integer transfer of sign
DSIGN(X,Y)	Double Precision transfer of sign
DIM(X,Y)	Real positive difference
IDIM(I,J)	Integer positive difference
EXP(X)	e raised to the X power (X is Real)
DEXP(X)	e raised to the X power (X is Double)
CEXP(Z)	e raised to the Z power (Z is Complex)
ALOG(X)	Returns the natural log of X (X is Real)
ALOG10(X)	Returns the log base 10 of X (X is Real)
DLOG(X)	Returns the natural log of X (X is Double)
DLOG10(X)	Returns the log base 10 of X (X is Double)
CLOG(Z)	Returns the natural log of Z (Z is Complex)
SQRT(X)	Square root of Real argument
DSQRT(X)	Square root of Double Precision argument
CSQRT(Z)	Square root of Complex argument
SIN(X)	Real sine
DSIN(X)	Double Precision sine
CSIN(Z)	Complex sine
COS(X)	Real cosine
DCOS(X)	Double Precision cosine
CCOS(Z)	Complex cosine
TANH(X)	Hyperbolic tangent
ATAN(X)	Real arctangent
DATAN(X)	Double Precision arctangent
ATAN2(X,Y)	Real arctangent of (X/Y)
DATAN2(X,Y)	Double Precision arctangent of (X/Y)
CONJG(Z)	Complex conjugate
RAN(I,J)	Returns a random number between 0 and 1

Chapter 13

The BASIC Language

BASIC is the Most Widely Used Language in the World Today.

BASIC is an acronym for Beginner's All-purpose Symbolic Instruction Code. BASIC was developed at Dartmouth College to answer the need for an easy-to-learn, conversational programming language accessible to people who are not computer specialists. Characteristics of the BASIC language include simple English words, understandable abbreviations, and the familiar symbols for mathematical and logical operations.

BASIC is the most widely implemented and most widely used programming language in the world today. Digital's BASIC language implementations have always been in the vanguard of the computer industry, and today, they are acknowledged as the industry leaders.

BASIC, in its interactive versions, like BASIC-PLUS and BASIC-11, gives the novice programmer almost immediate use of the computer, allowing him or her to get results for mathematical requests very easily. In addition, with little training the beginner can write and run meaningful programs. Interactivity encourages the new user to practice and experiment with the language, since there is a quick response from the computer telling whether the instruction worked and, if not, what went wrong. BASIC also includes powerful capabilities necessary to users who want to do file management, matrix manipulation, editing, and other more advanced computer operations.

Most of Digital's versions of BASIC offer the advantages of interactive program development, including powerful statement editing features plus HELP and debugging facilities. Their friendly environments have made BASIC one of the most popular programming languages in both commercial and technical applications, along with its traditional preeminence in academia.

Digital Offers Three PDP-11 BASIC Implementations.

The following paragraphs give a brief overview of Digital's three BASIC implementations.

BASIC-PLUS-2 Version 2

PDP-11 BASIC-PLUS-2 Version 2 is the most powerful, most advanced BASIC language implementation available on PDP-11 systems. As a true compiler, BASIC-PLUS-2 significantly improves the performance of compute-bound BASIC applications. Fast program execution and a variety of advanced programming features make BASIC-PLUS-2 a highly productive programming environment and powerful enough for a wide variety of applications. BASIC-PLUS-2 Version 2 is available on the RSX-11M-PLUS, RSX-11M,and RSTS/E operating systems and is generally a superset of BASIC-PLUS and a subset of VAX-11 BASIC. This makes BASIC-PLUS-2 Version 2 applications highly transportable across a wide variety of Digital systems. More detailed information on BASIC-PLUS-2 is included in the Product Descriptions section of this chapter.

BASIC-PLUS

BASIC-PLUS was specifically designed for and runs exclusively on RSTS/E as one of many language options. It is included with the operating system, and because of its conversational nature, is especially suited to timesharing environments.

Experienced programmers can use BASIC-PLUS's advanced features and facilities to produce complex and efficient programs. In general, BASIC-PLUS provides the following advantages:

- Programs can be written to conserve memory space and reduce execution time.
- Programs can handle a wide range of data by manipulating character strings.
- Programmers can obtain greater precision than is possible with floating-point and integer operands by using arithmetic and numeric string data manipulation.

It's not surprising that BASIC-PLUS is widely used for sophisticated scientific and business applications. Beginning programmers find BASIC-PLUS convenient and easy to use. BASIC-PLUS is also widely used as an educational tool in installations ranging from elementary schools to universities.

BASIC-11

BASIC-11 is an easy-to-learn programming language similar to Dartmouth standard BASIC. Like Dartmouth BASIC, it is a conversational language that uses simple English statements and familiar mathematical notation. Its immediate response and interactive features allow users to develop and debug programs in a minimum of time. It can be used for executing large data processing tasks and for performing

quick, one-time calculations. It also provides advanced techniques for intricate data manipulation and efficient problem solution. BASIC-11 is available on the RT-11, RT^2, and RT^2/PDT operating systems.

Digital's Versions Share Common Features.

The three BASIC implementations share syntax, language element, and file structure features. In addition, programs in all three implementations are created, modified, and executed in similar fashion.

General Syntax

A BASIC program is composed of groups of statements containing instructions to the computer. Each group begins with a number that identifies it as a statement and indicates the order of statement execution relative to other lines in the program. Each statement starts with an English word specifying the type of operation to be performed.

More than one statement can be written on a single line when each statement after the first is preceded by a backslash. For example:

```
10 INPUT A,B,C
```

is a single statement line, while

```
20 LET X=11\ PRINT X,Y,Z \IF X=A THEN 10
```

is a multiple statement line containing three statements: LET, PRINT, and IF.

BASIC Language Elements

In addition to real and integer formats, BASIC accepts exponential notation. Numeric data can be input in any one or all of these formats. BASIC automatically uses the most efficient format for printing a number, according to its size. It automatically suppresses leading and trailing zeros in integer and decimal numbers and formats all exponential numbers.

It can also process information in the form of strings. A *string* is a sequence of alphabetic, numeric, or special characters treated as a unit, either a constant or a variable.

A string constant is a list of characters enclosed in quotes that can be used in such diverse BASIC statements as PRINT, CALL, and CHAIN. String constants can also be used to assign a value to a string variable, for example, in the LET and INPUT statements, as with:

```
30 LET A$ = "HELLO"
```

Subscripted variables provide additional computing capabilities for dealing with lists, tables, matrices, or any set of related variables. In BASIC, variables are allowed either one or two subscripts. For example, a list of floating point values might be stored in an array A(I) where I goes from 0 to 5:

A(0), A(1), A(2), A(3), A(4), A(5)

This allows reference to each of the six elements in the list, and can be considered a one-dimensional algebraic matrix. Analogously, you can construct two-dimensional arrays by using two subscripts. For example:

B(I,J)

where I goes from 0 to 3 and J goes from 0 to 5, defines a 24-element matrix.

Any variable name followed by a percent sign (%) indicates an integer variable. For example: A%, C7%, C%(5).

Any variable name followed by a dollar sign ($) character indicates a string variable (for example: A$, C7$), while a matrix variable name followed by the dollar sign character denotes the string form of that variable (for example: V$(n), M2$(n), C$(m,n), G1$(m,n)).

Variables without % or $ suffixes are considered floating point variables; for example, A, B7, C(I), D(J,K).

The user can assign values to variables by using a LET statement, by entering the value as data in an INPUT statement, or by using a READ statement with associated data statements. Values assigned to a variable do not change until the next time a statement that contains a new value for that variable is encountered.

Operators

BASIC performs addition, subtraction, multiplication, division and exponentiation. IF-THEN statements have access to a variety of relational operators (less than, not equal, greater than or equal to, for example). Most operators of both kinds work with strings as well as with numerical arguments; for strings, the relational operators do alphabetic comparisons.

Statements

The following summary of BASIC statements gives a brief explanation of each statement's use.

CALL	Transfers control to a subprogram, optionally passes parameters to it, and stores the location of the calling program for an eventual return.
CHAIN	Terminates execution of the program, loads the program specified, and begins execution of the lowest line number or, when a line number is present in the statement, at the specified line number.
CLOSE	Closes the file(s) associated with the logical unit number(s) and virtual file logical unit number(s).
DATA	Creates a data block for the READ statement. Can contain any combination of strings and numbers.
DEF FN	Defines a user function.
DIM	Reserves space in memory for arrays according to the subscripts specified.

END	Placed at the end of the physical end of the program to terminate execution (optional).
FOR	Sets up a loop to be executed the specified number of times.
GOSUB	Unconditionally transfers control to specified line of subroutine.
GO TO	Unconditionally transfers control to specified line number.
IF	Conditionally executes the specified statements or transfers control to the specified line number. If the condition is not satisfied, execution continues at the next sequential line. The expressions and the relational operator must all be string or all be numeric.
INPUT	Inputs data from a file or from the user's terminal. Variables can be arithmetic or string.
KILL	Deletes the specified file.
LET	Assigns the value of an expression to the specified variable(s).
NAME AS	Renames the specified file.
NEXT	Placed at the end of the FOR loop to return control to the FOR statement.
ON GOSUB	Conditionally transfers control to the subroutine at one line number specified in the list. The value of the expression determines the line number to which control is transferred.
ON GO TO	Conditionally transfers control to one line number in the specified list. The value of the expression determines the line number to which control is transferred.
OPEN FOR INPUT [OUTPUT] AS FILE #n	Opens a file for input [or output] and associates the file with the specified logical unit number or channel number.
OVERLAY	Merges the current program with a program segment stored in a file (BASIC-11 only).
PRINT	Prints the values of the specified expressions on the terminal or, when specified, to the file associated with the logical unit expression. The TAB function can also be included.
PRINT USING	Generates output formatted according to a format string (either numeric or string).
RANDOMIZE	Causes the random number generator (RND function) to produce different random numbers every time the program is run.
READ	Assigns values listed in DATA statements to the specified variables. These variables can be numeric or string.
REM	Contains explanatory comments in a BASIC program.
RETURN	Terminates a subroutine and returns control to the statement following the last executed GOSUB statement.
RESTORE	Resets to the beginning the data pointer.
STOP	Suspends execution of the program.

FUNCTIONS

BASIC provides a variety of functions to perform mathematical and string operations.

Arithmetic Functions

ABS	Returns the absolute value of an expression.
ATN	Returns the arc tangent as an angle in radians.
COS	Returns the cosine of an expression in radians.
EXP	Returns the value of the constant e (approximately 2.71828) raised to a given power, which can be an (expression).
INT	Returns the greatest integer less than or equal to a given expression.
LOG	Returns the natural logarithm of an expression.
LOG10	Returns the base 10 logarithm of an expression.
PI	Returns the value of pi (3.141593 approximately).
RND	Returns a random number between 0 and 1.
SGN	Returns value indicating the sign of an expression.
SIN	Returns the sine of an expression in radians.
SQR	Returns the square root of an expression.
TAB	Causes the terminal print head to tab to column number given by an expression (valid only in PRINT).
SYS	Special system function calls; controls terminal I/O and performs special functions.

String Functions

CHR$	Generates a one-character string whose ASCII value is the low-order eight bits of the integer value of the given expression.
TIME$	Returns the time as a string.
DATE$	Returns the date as a string.
LEN	Returns the number of characters in the given string.
POS	Searches for and returns the position of the first occurrence of a substring in a string.
SEG$/MID	Returns the string of characters in the given positions in the string.
STR$	Returns the string which represents the numeric value of the given expression.
TRM$	Returns the given string without trailing blanks.
VAL	Returns the value of the decimal number contained in the given string expression.

User-Defined Functions

In some programs it may be necessary to execute the same sequence of statements in several different places. BASIC allows definition of unique operations or expressions and the calling of these functions in the same way as, for example, the square root or trigonometric functions. Each function is defined once and can appear anywhere in the program. User-defined functions simplify program entry, contribute to modular coding, and help to streamline programs..

BASIC Files

Data are stored either in sequential files or in random access, virtual array files. Data are read by an INPUT statement and written by a PRINT statement. Virtual arrays are random-access, disk-resident files that are similar to arrays stored in memory. A program can create and access virtual arrays just as it accesses memory-resident arrays: using array names and subscript values. Because the arrays are stored on disk, programmers can manipulate large amounts of data without affecting program size.

BASIC-PLUS-2 also supports the RMS-11 Record Management System. Through RMS-11, BASIC-PLUS-2 provides virtual array, block I/O, terminal-format, sequential, relative, and indexed files.

Creating, Modifying, and Executing BASIC Programs

A BASIC program is entered in the system using the editing commands. Once the program has been entered, it can be retrieved, listed, modified, or executed using the editing commands. These commands are:

APPEND	Merges the program currently in memory with a program stored in a file. All lines in the program in memory that have duplicate line numbers with the program in the file are replaced by the lines from the program in the file.
BYE	Terminates the session at the terminal.
CLEAR	Used when a program has been executed and then edited. Before rerunning the program, the array and string buffers are cleared to provide more memory space (interpreters only).
LENGTH	Displays on the terminal the amount of storage required by the BASIC-11 program currently in memory. This information is useful in determining the minimum user area in which a specific program can run.
LIST LISTNH	Types on the terminal the program currently in memory. A range of line numbers can be specified. The "NH" suffix suppresses header printing.
NEW	Clears the user area in memory and assigns a specified name to the current program. Used to create a new program.
OLD	Clears the user area and reads a program from a specified file into the user area in memory.

RENAME	Changes the current program name to a specified name.
REPLACE	Replaces the specified file with the program currently in memory.
RESEQ	Allows a user to resequence the line numbers in a program. (BASIC-11 only)
RUN RUNNH	If issued with no file specification, executes the program currently in memory. If a file specification is issued, clears the user area, reads a program in from the file, and executes the program. The "NH" suffix suppress header printing. (not BASIC-PLUS-2/RSX)
SAVE	Copies the contents of the user area to a file, lists the contents on the lineprinter, or punches the contents on papertape.
UNSAVE	Deletes the specified file.

In addition to the editing commands, the BASIC system recognizes the following special control characters:

CTRL/C	Interrupts program execution and prints the READY message.
CTRL/O	Enables/disables console output.
CTRL/U	Deletes the current line being typed.
RUBOUT	Deletes the last character typed.

BASIC-PLUS-2 is a Truly Structured Language.

BASIC-PLUS-2 Version 2 is the most powerful and advanced BASIC available on PDP-11 systems. It combines a powerful implementation language compiler with an integrated set of program development utilities. Fast program execution is one way BASIC-PLUS-2 helps improve programmer productivity. A language-integrated I/O syntax conveniently accesses the RMS-11 record/file handling facilities. CALL statements allow modular structuring of programs. MAP statements permit variable-oriented data record access.

BASIC-PLUS-2 generates "threaded code." Threaded code executes at high-speed and produces smaller object programs than conventional inline instruction generation. Smaller programs mean fewer overlays are needed, fewer trips to disk are necessary, and throughput is higher.

Language Features

BASIC-PLUS-2's language features provide greater programmer flexibility, more language statements, more sophisticated data typing and manipulation, and, through RMS, easier file access than most other BASIC implementations—including Digital's BASIC-PLUS.

With the advent of Version 2, BASIC-PLUS-2 is now a truly structured language, allowing a "self-documenting" code that can be more quickly understood. It also has a built-in modularity that makes it easier to add new modules or modify old ones. This structured programming is supported in the following ways.

- Up to 31 alphanumeric characters can be used for variable and function names and statements labels, allowing for self-documenting names that indicate their use in the program. These labels can also be used in place of line numbers in most parts of the program.
- *Block-structured statements* such as IF...THEN...ELSE...END IF and SELECT...CASE...END SELECT allow programmers to directly implement structured code without resorting to makeshift shortcuts and excessive commenting.
- *User-named program constants* let programmers give meaningful names to often-used values in a program, such as integers that represent TRUE, FALSE, SUCCESS, and FAILURE Flags.

Flexibility in program formatting allows programmers to arrange their source programs so that the functional blocks and the flow of the program can be easily identified.

Program Segmentation allows a program to be constructed of seperately compiled modules headed by the SUB or FUNCTION statements, to be subsequently accessed by the main module. Segmentation makes it easier to modify the program and gives programmers more flexibility in overlaying.

The CALL statement can pass parameters BY VALUE, REFerence, or DEScriptor.

The EXTERNAL statement provides access to global variables, functions and constants, and allows data typing of parameters to aid in minimizing runtime mismatches.

The OTHERWISE clause ON GOTO and ON GOSUB provides a simple solution when the index expression is out of range.

Data Typing and Declarations

BASIC-PLUS-2 Version 2 has three general data types: *integer*, *floating point*, and *string*. There are further subdivisions within integer and floating point that determine the storage requirements, range, and precision of the data type. In addition, there is a specialized data type called RFA that can only contain a record file address and is used with record file address I/O operations.

With these data types the dollar sign ($) and percent sign (%) are usually unnecessary. While they are still used for undeclared strings and integers, they are not used for explicitly declared data types or with the DECLARE statement.

The DECLARE statement is used to explicitly declare variables, FUNCTIONS, CONSTANTS, and their data types. The DECLARE FUNCTION statement is used to define an internal function, including the function data type, number of arguments, and data type of the arguments. The DECLARE CONSTANT statement allows for the naming of constants and the assigning of a value to that constant.

Variables may be used in BASIC-PLUS-2 programs without being “declared” to the compiler. Scalar (that is, single-value) variables that are not declared are assigned storage from a general dynamic storage area which is available to the cur-

rent program (or subprogram) only. Undeclared arrays have dimension size of 10, if one dimensional, or 10 by 10, if two dimensional. The DIMENSION statement is used to declare arrays with a size other than the default.

COMMON and MAP Statements

The COMMON and MAP declarations are used to declare variables or arrays in a static, named storage area, accessible to other subroutines in the program image.

The COMMON statement defines a named, shared area of memory called a COMMON block, occupied by specified variable values. These values can be read or changed by any BASIC-PLUS-2 subprogram with a COMMON block of the same name. The COMMON statement enables a subprogram to pass data to another program or subprogram. Strings passed in COMMON are fixed length, thus reducing string handling overhead.

COMMON and MAP are similar in function. The MAP statement allocates record buffer space. With MAP, users create a storage area that will serve as an I/O buffer associated with one or more open I/O channels. The MAP feature is unique to PDP-11 BASIC-PLUS-2 and VAX-11 BASIC—no other BASIC implementation provides it. MAPs save program space and perform better than other methods of declaring variables. Because a MAP statement defines fixed-length character strings, it provides maximum control over storage allocation and reduces overhead. And, because MAP statements define data types at compile time, execution time is faster.

MAP DYNAMIC

BASIC-PLUS-2 Version 2 also features a MAP DYNAMIC statement, which names the variables and arrays whose size and position in a MAP buffer can change at runtime. All pointers are set to the beginning of the MAP buffer by the MAP DYNAMIC statement. Once defined, the sizes and positions of these variables and arrays are changed with the REMAP statement.

Functions

A function performs one or more operations on a specified set of arguments and returns a result, either numeric or string, to the calling program. BASIC-PLUS-2 provides both library and user-defined functions.

String Handling Functions

With BASIC-PLUS-2, programmers can concatenate and compare strings; convert string and numeric representations; and analyze the composition of strings. BASIC-PLUS-2 includes string functions that:

- Create a string containing a specified number of identical characters
- Locate a substring within a longer string
- Edit a string: change lowercase to uppercase; change square brackets to parentheses; trim trailing blanks/tabs from a string; delete form feeds, rubouts, line feeds, carriage returns, and nulls; trim parity, etc.
- Determine the length of a string

BASIC-PLUS-2 also supports string functions to perform string-to-numeric and numeric-to-string conversions. Unlike many BASIC languages, BASIC-PLUS-2 imposes no limit on the size of string values or string elements of arrays manipulated in memory, other than the amount of available memory.

Mathematical and Numeric String Functions

BASIC-PLUS-2 provides algebraic, exponential, trigonometric, and random number functions. In addition, its string arithmetic functions permit greater precision—up to 56 digits—than floating-point calculations. BASIC-PLUS-2 also includes matrix functions for transposing and inverting matrixes.

Program Control Constructs

In a BASIC program, control ordinarily moves from one line to another in consecutive line order. Within a line, control moves from statement to statement. However, execution can be diverted from the normal sequence to another portion of a program or to a subprogram, continue execution at that point, and then return control to the original program. BASIC-PLUS-2 provides a variety of methods to control program execution sequence. These include:

- Subroutine constructs
- CALL statement for subprograms
- Statement modifiers

Programmers can use BASIC-PLUS-2 to write structured programs much as they would use structured programming languages like PASCAL. Structured programs are easier to write and maintain than conventional programs.

Subroutines

A subroutine is a block of statements within a program that performs an operation and returns program control to the statement following the subroutine reference. The BASIC-PLUS-2 subroutine constructs use GOSUB, ON GOSUB, and RETURN statements.

Subroutines differ from functions and subprograms. A subroutine is a sequence of instructions to be executed several times in the course of a program. User-defined functions define a mathematical expression to be evaluated once, which then can be used repeatedly throughout a program. Subprograms are program units that can be separately compiled and then invoked from an external program.

Subprograms

Separately compiled subprograms can be invoked using the CALL statement. Subprograms:

- Divide large programs into more manageable units
- Provide a convenient means for executing frequently used programs
- Permit control to transfer from one program to another
- Permit program overlays to conserve memory

Statement Modifiers

Programmers can use statement modifiers for conditional or repetitive execution of a statement. Modifiers save program text space and increase readability. Any non-declarative statement in BASIC-PLUS-2 can have one of the five supported statement modifiers: FOR, IF, UNLESS, UNTIL, and WHILE.

Modifiers cannot stand alone; they *must* be appended to a statement, and all executable BASIC-PLUS-2 statements can be modified.

When using statement modifiers with the various forms of the IF statement, the following rules apply:

- Append statement modifiers to either the THEN clause or the ELSE clause of an IF statement.
- The statement modifier applies only to the clause it is appended to and not to the statement as a whole.

If there is more than one statement on a line, the modifier applies only to the statement immediately preceding it. More than one statement modifier can be appended to a single statement. In this case, BASIC-PLUS-2 processes the modifiers from right to left.

Matrix Operations

With the MAT statement, the following operations can be performed on arrays:

- Assignment
- Addition
- Subtraction
- Multiplication
- Transposition
- Inversion

Each MAT operation statement begins with the keyword MAT followed by an expression to be evaluated. The value of one array can be assigned to another, for example, as in:

```
MAT A=B
```

This statement sets each entry to array A equal to the corresponding entry of array B. A is redimensioned to the size of array B.

Files and Records

A major distinction between BASIC-PLUS-2 and BASIC-PLUS is access to the Record Management Services (RMS) with BASIC-PLUS-2. RMS greatly increases the ease with which programmers can develop and run complex programs.

There are four types of files in BASIC-PLUS-2:

- RMS record files
- Terminal format files

- Virtual array files
- RSTS native (block I/O)

RMS-11

RMS-11 is a record and file management system that provides a variety of file organizations and access modes. Through RMS, BASIC-PLUS-2 provides virtual array, block I/O, terminal format, sequential, relative, and indexed files. This variety means users can choose file organizations and access methods best suited to individual applications.

BASIC-PLUS-2 has specific language elements for creating a file, describing the attributes of a file, opening a file, associating a record buffer with the file, describing the contents of the record buffer, performing input/output operations on a file, and allowing multiuser access to a file. With specific language elements for each of these operations, a CALL statement is not necessary for performing file handling functions. Because programmers can deal with logical records rather than with physical disk blocks, record and file handling is much easier than with other BASIC systems.

Terminal Format Files

A terminal format file is a stream of ASCII characters stored in lines of various lengths. The end of a line is determined by a line terminator, for example, line feed. BASIC-PLUS-2 stores these ASCII characters, including spaces and line terminators, exactly as they would appear on the terminal; hence the name terminal format file.

Terminal format files are sequential access files (that is, they contain records that must be read or written one after another from the beginning of the file). This means that a record cannot be retrieved without first retrieving each of the items preceding it in turn.

BASIC-PLUS-2 maintains a file pointer that keeps track of the user's location in the file. To add new items to an existing file without overwriting current information, the entire file must be read. This action places the file pointer at the end of the file where data can be added.

Virtual Array Files

A virtual array file, like a terminal format file, is information stored on a disk. Once a virtual array file is opened, however, the similarity with terminal format files ends. Elements in a virtual array can be accessed exactly as elements in an array in memory.

Virtual array files are random access files. The last element in a virtual array can be accessed as quickly as the first.

When BASIC-PLUS-2 stores data in a virtual array file, it does not convert them to ASCII characters but rather stores them in the internal binary representation. Consequently, there is no loss of precision caused by data conversion.

RTS Native (Block I/O)

Block I/O files make possible the most flexible and efficient technique of data transfer available under BASIC. Language extensions handle records composed of fixed-length fields, while disk and magnetic tape I/O operations read and write sequential data blocks. For disk files, the programmer can optionally specify a record or block number, thereby having complete random access to the file.

Programmers can dynamically define the record buffer area of a file as a series of fields and subfields. Alphanumeric data can be moved into a fixed-length field using either automatic truncation or padding (with spaces), depending upon the relative lengths of the source and destination fields. Space in the record can be saved by packing the numeric fields using numeric/string conversion functions.

Cluster Libraries

Cluster libraries allow you to write larger programs than you would otherwise be able to by letting two or more resident libraries begin at the same address in a program. Although only one library in each cluster can be mapped at any given moment, a cluster library is automatically mapped whenever the program calls a subroutine in a library.

Many Digital-supplied libraries of service routines and language routines, such as FMS and RMS, can be clustered. Users can also construct their own library clusters. Each cluster will have a default library plus one or more additional libraries that can take over the assigned set of virtual addresses.

BASIC-PLUS Runs On RSTS/E.

Functions and Features

The BASIC-PLUS language interpreter enables you to write programs in BASIC-PLUS and to interact with the RSTS/E operating system. BASIC-PLUS runs exclusively on RSTS/E.

BASIC-PLUS incorporates the following features.

- *Immediate Mode*: Commands can be executed immediately by BASIC-PLUS instead of being stored for later execution.
- *Program Editing*: An existing program can be edited by adding or deleting lines, or renaming the program. The user can combine two programs into a single program and request the listing of a program, either in whole or in part, on a terminal or lineprinter.
- *Program Control and Storage*: Facilities are included for storing both programs and data on any mass storage device and retrieving them later for use during program execution.

- *Documentation and Debugging*: The insertion of remarks and comments within a program is easy in this version of BASIC. Program debugging is aided by the printing of meaningful diagnostic messages that pinpoint errors detected during the program's execution.
- *Access to System Peripheral Equipment*: The user program is able to perform input and output with various equipment, such as disk, industry-compatible magnetic tape, lineprinter, and floppy disks.
- *Record I/O*: Language extensions provide a means of handling records composed of fixed-length fields in a highly efficient manner.
- *Matrix Computations*: A set of commands is available for performing matrix I/O, addition, subtraction, multiplication, inversion, and transposition.
- *Alphanumeric Strings*: Alphanumeric strings can be manipulated with the same ease as numeric data. Individual characters within these strings are accessible to the user.
- *Output Formatting*: The PRINT and PRINT-USING statements include facilities for tabs and spaces as well as precise specifications of the output line formatting and floating dollar sign, asterisk fill, and comma insertion in numeric output.

String Arithmetic: A set of functions performs arithmetic on operands which are numeric strings instead of integer or floating point numbers. This provides a means of calculating values of higher than normal precision, or values which must not be affected by round-off error (at the expense of slower execution time).

Immediate Mode Operations

Most BASIC-PLUS statements can either be included in a program for later execution or be issued online at the terminal as commands to be immediately executed by the BASIC language processor. Immediate mode operation is especially useful in two ways: to perform simple calculations that do not justify writing a complete program; and to debug a program.

To make program debugging easier, you can insert several STOP statements in the program. When the program is run, each STOP statement causes the program to halt and identify the line in the program at which the program was interrupted. You can then examine the current contents of variables and change them if necessary, and then continue.

Data Formats and Operations

BASIC-PLUS allows you to manipulate string, integer numeric, or floating point numeric data. BASIC-PLUS permits a user program to combine integer variables or integer-valued expressions using a logical operator to give a bitwise integer result. The logical operators AND, OR, NOT, XOR, IMP, and EQV operate on integer data in a bitwise manner.

BASIC-PLUS users working with floating point numbers can increase accuracy of operations involving fractional numbers by using the scaled arithmetic feature or

the string arithmetic functions. Furthermore, users can perform arithmetic operations using a mix of integer and floating point numbers. If both operands of an arithmetic operation are either explicitly integer or explicitly floating point, the system automatically generates integer or floating point results. If one operand is an integer and another is floating point, the system converts the integer to a floating point representation and generates a floating point result. If one operand is an integer and the other operand is a constant that can be interpreted either as a floating point number or an integer, the system generates an integer result.

Matrix Manipulation

Variables of any type are legal in matrixes, though any particular matrix must be composed of a single type of data. Explicitly dimensioning a matrix establishes the number of elements in each row and column and the number of elements in the matrix. (Implicitly dimensioned matrixes are assumed to have 10 elements in each dimension referenced.) Explicit dimensioning is done using the DIM statement.

By using the matrix I/O (MAT) statements, you can alter the number of elements in each row and the number of columns in the matrix, as long as the total number of elements does not exceed the number defined when the matrix was dimensioned. The MAT operations do not set row zero or column zero, nor do they initialize values in the space allocated to the matrix unless specific MAT functions are executed.

The operations of addition, subtraction, and multiplication (including scalar multiplication) can be performed on matrices using the common BASIC mathematical operators; functions also exist for performing transposition and inversion of matrixes.

Advanced Statement and Function Features

BASIC-PLUS extends the BASIC language by including several additional statements for easier logic flow control, function definitions, and faster response in a timesharing environment. The ON-GOTO, ON-GOSUB, IF-THEN-ELSE, FOR-WHILE, and FOR-UNTIL statements provide a variety of conditional controls over looping and subroutine execution. The ON ERROR GOTO statement allows the programmer to write subroutines that handle error conditions normally considered fatal. The program can test a system variable named ERR to determine which error occurred, and can examine a system variable named ERL to determine the line number at which the error occurred. SLEEP and WAIT allow program suspension, either for a specified time interval or until input from a terminal is received. The PRINT-USING statement provides special output formatting, including exponential representation, dollar signs, commas, trailing minus sign, and asterisk fill. The DEF statement allows multiple-line function definitions. Multiple-line function definitions can be nested, can be written in any data type, and can contain any variety of argument types.

Five statement modifiers are available within BASIC-PLUS; IF, UNLESS, FOR (including FOR-WHILE and FOR-UNTIL), WHILE, and UNTIL. These modifiers are appended to program statements to indicate conditional execution of the statement or the creation of implied FOR loops.

RSTS/E also includes several system functions and statements that allow program access to system information and conversion routines. The program can obtain the current date and time, the CPU time, connect time, kilocore ticks, and device time used for the job. It can convert a numeric value to a string date or time or vice versa, can swap bytes, or convert an integer in RADIX-50 format to a character string.

Table 13-1 BASIC Language Features—PDP-11

	ANSI Minimal	BASIC +2 RSTS	BASIC +2 RSX	BASIC -PLUS	BASIC -11 RT-11
Implementation Limits					
31-char names Up to 31 character variable names	–	X	X	X	–
Dynamic strings String length 32767 or max memory	–	X	X	X	–
Implicit continuation IF Statements implicitly continued over multiple line	–	X	X	–	–
Labels Statement labels up to 31 characters	–	X	X	–	–
Max line 32767 Maximum line number allowed	–	X	X	X	X
Multiline stmt Carry one statement across lines	–	X	X	X	–
Multistmt line Several statements on one line	–	X	X	X	X
Data Types, Constants, and Variables					
16-bit integer (WORD) Integer variables and constants	–	X	X	X	X
32-bit integer (LONG) 32-bit integers	–	X	X	–	–
8-bit integer (BYTE) Integer variables and constants	–	X	X	–	–
COMMON (X) I,J.. Defines a common data segment	–	X	X	–	*
CR,LF,FF,ESC... Predefined string literals	–	X	X	–	–
DATA 1,2,3,... Stores data for use by READ	X	X	X	X	X
DECLARE <type> Explicit data typing	–	X	X	–	–
DIM A(X [,Y]) Up to two dimensions	X	X	X	X	X
DIM A(X[,Y]...) More than two dimensions	–	X	X	–	X
DOUBLE name Floating point variables and constants		X	X	X	X
ESC$ ASCII escape char: CHR$ (27)		*	*	–	–
EXTERNAL type External variables and functions	–	X	X	–	–

* Product performs function, using different command.

Table 13-1 (Cont.) BASIC Language Features—PDP-11

	ANSI Minimal	BASIC +2 RSTS	BASIC +2 RSX	BASIC -PLUS	BASIC -11 RT-11
Data Types, Constants, and Variables (Continued)					
MAP (name) list Static data region <name>, has <list> variables	–	X	X	–	–
MAP DYNAMIC (name) Specifies fields to be allocated at runtime within name	–	X	X	–	–
PI Returns 3.14159...	X	X	X	X	X
Packed DECIMAL Data type, up to 31 digits precision	–	–	–	–	–
RECORD name User-defined data structure (like PASCAL or COBOL)	–	–	–	–	–
REMAP (name) <list> Runtime determination of I/O fields in a MAP DYNAMIC	–	X	X	–	–
SINGLE real Floating point variables and constants	X	X	X	X	X
STRING A,B,... Declares a string variable	–	*	*	–	–
VARIANT (See RECORD), alternative field definition in a RECORD	–	–	–	–	–
Expressions and Assignments					
** Raise to a power		X	X	X	–
== arith-op Approximate compare: numeric	–	X	X	X	–
== string-op Exact string compare (trailing spaces count)	–	X	X	X	–
A,B,C = <exp> Multiple assignments in one statement	–	X	X	X	–
AND Logical operator	–	X	X	X	–
Arith-exp's + – * / ^	X	X	X	X	X
CONCATENATE "+" Joins string values	–	X	X	X	X

* Function performed by product, uses different command.

Table 13-1 (Cont.) BASIC Language Features—PDP-11

	ANSI Minimal	BASIC +2 RSTS	BASIC +2 RSX	BASIC -PLUS	BASIC -11 RT-11
Expressions and Assignments (Continued)					
EQV Opposite of XOR	–	X	X	–	X
IMP 0 if first 1 and second arg = 0	–	X	X	–	–
LET A = exp Optional, starts assignment statement	X[1]	X	X	X	X
LSET A$=str-exp Left justifies data into random access field	–	X	X	X	–
NOT Logical negate	–	X	X	X	–
OR Logical operator	–	X	X	X	–
RSET A$ = str-exp Right justifies data into random access field	–	X	X	X	–
Relational-exp <>=<=>=<>	X	X	X	X	X
Stmt-modifiers Statement modifiers: FOR, IF, UNLESS, UNTIL, WHILE	–	X	X	X	–
XOR Exclusive OR – a logical operator	–	X	X	X	–
Trigonometric Functions					
ATN(X) Computes arc tangent	X	X	X	X	X
COS(X) Computes cosine	X	X	X	X	X
SIN(X) Computes sine, argument in radians	X	X	X	X	X
TAN(X) Computes tangent, argument in radians	X	X	X	–	–
Mathematic Functions					
ABS%(X) Returns integer, absolute value	–	X	X	–	–
ABS(X) Computes absolute value	X	X	X	X	X
COMP%(A$,B$) Compares two num-strings	–	X	X	X	–

* Product performs function, using different command.
1 Not optional for ANSI Minimal.

Table 13-1 (Cont.) BASIC Language Features—PDP-11

	ANSI Minimal	BASIC +2 RSTS	BASIC +2 RSX	BASIC -PLUS	BASIC -11 RT-11
Mathematic Functions (Continued)					
DET Determinant from MAT INV	—	X	X	—	—
DIF$(A$,B$) String dif of two num-strings	—	X	X	X	—
EXP(X) Computes natural antilog	X	X	X	X	X
FIX(F) Truncates fractional part	—	X	X	X	X
INT(X) Largest integer not greater than argument	X	X	X	X	X
LOG(X) Natural log	X	X	X	X	X
LOG10(X) Returns base 10 log	—	X	X	X	X
MAG(X) Returns absolute value, with same data type as argument (ABS always returns Floating)	—	X	X	—	—
NUM Last row of last MAT input	—	X	X	—	—
NUM2 Column number, last element of MAT input	—	X	X	—	—
PLACE$(S,N) Precision of S$ set by n	—	X	X	X	—
PROD$(S,S,R) String product s*s	—	X	X	X	—
QUO$(S,S,R) String quotient	—	X	X	X	—
RND [(0)] Returns random number between 0 and 1	*	X	X	X	X
RND(N) Returns random number between 1 and argument	X	*	*	*	—
SGN(X) Returns the sign of a value	X	X	X	X	X

* Product performs function, using different command.

Table 13-1 (Cont.) BASIC Language Features—PDP-11

	ANSI Minimal	BASIC +2 RSTS	BASIC +2 RSX	BASIC -PLUS	BASIC -11 RT-11
Mathematic Functions (Continued)					
SQR(X) Computes square root	X	X	X	X	X
SUM$(S,S,R) String addition	—	X	X	X	—
String and Formatting Functions					
CVT$$(A$,N) String editing function	—	X	*	X	—
EDIT$ String editing function	—	X	X	—	—
FORMAT$(X,A$) Expression -> formatted output string	—	X	X	—	—
INSTR(S,A$,B$) Returns starting position of a substring	—	X	X	X	*
LEFT$(A$,6) Returns left portion of a string	—	X	X	*	X
LEN(A$) Returns the number of characters in a string	—	X	X	X	X
MID$(A$,S,L) Returns substring within a string	—	X	X	*	*
NUM$(EXP) String = PRINT format	—	X	X	X	—
NUM1$(EXP) NUM$, without spaces	—	X	X	—	—
POS(A$,B$,P) Returns start index of B$ in A$, begins at column P	—	X	X	—	X
RIGHT$(A$,N) Returns right portion of a string	—	X	X	*	—
SEG$(A$,ST,ND) Extracts a substring from a string	—	X	X	*	X
SPACE$(X) Returns a string of X spaces	—	X	X	X	—
STR$(N) Converts a numeric value to a string	—	X	X	*	X
STRING$ Returns a string of n identical characters	—	X	X	X	—

* Product performs function, using different command.

Table 13-1 (Cont.) BASIC Language Features—PDP-11

	ANSI Minimal	BASIC +2 RSTS	BASIC +2 RSX	BASIC -PLUS	BASIC -11 RT-11
String and Formatting Functions (Continued)					
TRM$(S)					
Removes trailing blanks, tabs	–	X	X	*	X
VAL%(I)					
Integer value of string I	–	X	X	–	–
VAL(N$)					
Evaluates a string, returns a number	–	X	X	X	X
XLATE(S1,S2)					
Translate. S2=table	–	X	X	X	–
Time and Date Functions					
CLK$					
Returns HH:MM:SS time	–	*	*	*	X
DATE$ [(N)]					
Returns current date, 18-character string	–	X	X	X	–
TIME[$] (N)					
Returns time in 24-hour format string	–	X	X	X	X
Data Conversion Functions					
ASC(A$)					
Returns ASCII code of first character	–	X	X	X	X
ASCII(A$)					
Code for character	–	X	X	X	–
CHR$(N)					
Returns ASCII character	–	X	X	X	X
CVT$%(A$)					
Two characters -> integer	–	X	X	X	–
CVT$F(A$)					
Four characters – floating point	–	X	X	X	–
CVT%$(I%)					
Integer -> two characters	–	X	X	X	–
CVTF$(X)					
Floating value -> four characters	–	X	X	X	–
DECIMAL(X[,D,S])					
Forces conversion to DECIMAL	–	–	–	–	–
INTEGER(X {,BYTE ,WORD ,LONG})					
Forces conversion to INTEGER	–	X	X	–	–
OCT$(N)					
Computes octal value, returns string	–	–	–	–	X

* Product performs function, using different command.

Table 13-1 (Cont.) BASIC Language Features—PDP-11

	ANSI Minimal	BASIC +2 RSTS	BASIC +2 RSX	BASIC -PLUS	BASIC -11 RT-11
Data Conversion Functions (Continued)					
RAD$(N) RAD-50 equivalent	–	X	X	X	–
REAL(X {,SINGLE ,DOUBLE ,GFLOAT ,HFLOAT}) Forces conversion to REAL	–	X	X	–	–
Input/Output Functions					
BUFSIZ(C) Returns buffersize for #c	–	X	X	X	–
CCPOS(N) Current character position in channel	–	X	X	*	–
FSP$(N) File description, channel #N	–	X	X	–	–
INKEYS Gets keyboard character, if available		*	*	–	*
MAGTAPE(FN,X,N) Magtape handling. F=function, X=number of records, N=channel	–	X	X	X	–
ONECHR(N) Starts 1-character input mode on #N	–	X	X	–	–
RECOUNT Length of last input	–	X	X	X	–
SPC(N) Prints a line of n spaces		*	*	*	–
SPEC%(...) RSTS peripheral control functions	–	X	–	X	–
STATUS Return host status/OPEN	–	X	X	X	–
Miscellaneous Functions					
FRE(A$) Returns amount of unused string space	–	*	*	–	–
FRE(X) Returns total amount of free memory space		*	*	–	–
LOC(X) Returns address of variable	–	–	–	–	–
MEM Returns the amount of free memory	–	*	*	–	*

* Product performs function, using different command.

Table 13-1 (Cont.) BASIC Language Features—PDP-11

	ANSI Minimal	BASIC +2 RSTS	BASIC +2 RSX	BASIC -PLUS	BASIC -11 RT-11
Miscellaneous Functions (Continued)					
PEEK(X)					
Returns memory contents at byte X (AKA: EXAM[INE])	—	*	—	*	—
RCTRLO					
Override effect of ^O, resume output	—	X	X	—	X
SWAP%(X)					
Transposes low two bytes	—	X	X	X	—
SYS$(A$)					
RSTS/E service call	—	X	—	X	—
User Definition of Subroutines and Functions					
DEF FN...FNEND					
Multi-statement DEF....FNEND	—	X	X	X	—
DEF FNx(...)=exp					
Defines a user function	X	X	X	X	X
END DEF					
Define lexical end of a DEF	—	X	X	*	—
SUB NN(A,...,Z)					
Defines CALLable subroutine and arguments	—	X	X	—	—
Control Statements					
CALL name(args)					
Transfer control to a SUBROUTINE	—	X	X	—	*
CHAIN F					
Load and execute specified program	—	X	X	X	—
END					
END program execution	X	X	X	X	X
END FUNCTION					
Delimits end of DEC BASIC FUNCTION	—	X	X	—	—
END IF					
Structured end of IF (vs. line number)	—	X	X	—	—
END SUB					
Defines lexical end of a SUB	—	X	X	—	—
EXIT					
Return to system level	—	—	—	X	*
EXIT					
Exit a labeled block	—	X	X	—	—
EXIT LABEL					
Structured BLOCK EXIT statement	—	X	X	—	—

* Product performs function, using different command.

Table 13-1 (Cont.) BASIC Language Features—PDP-11

	ANSI Minimal	BASIC +2 RSTS	BASIC +2 RSX	BASIC -PLUS	BASIC -11 RT-11
Control Statements (Continued)					
FOR-NEXT Program loop	X	X	X	X	X
FUNCTION N(args) Separate FUNCTION subprogram	–	X	X	–	–
EXIT DEF Exit from DEC BASIC DEF	–	X	X	–	–
EXIT FUNCTION Exit from DEC BASIC FUNCTION	–	X	X	–	–
EXIT SUB Exit from DEC BASIC SUB	–	X	X	–	–
GOSUB NNNNN Transfers control to an internal subroutine	X	X	X	X	X
GOTO NNNNN Transfers control to a specific line number	X	X	X	X	X
IF <EXP> ... Conditional statement	X	X	X	X	X
IF-THEN-ELSE Conditional statement with alternative	–	X	X	X	–
ITERATE <label> Structured equiv. of GOTO..NEXT in a loop		X	X	–	–
ON GOSUB..OTHER OTHERWISE out-of-range target for ON GOSUB		X	X	–	–
ON GOTO ...OTHER OTHERWISE out-of-range target for ON GOTO		X	X	–	–
ON X GOTO/GOSUB Multiway branch with GOTO, GOSUB	X	X	X	X	X
RETURN Returns from a subroutine called by GOSUB	X	X	X	X	X
SELECT..CASE Structured CASE statement		X	X	–	–
STOP Stops execution of a program	X	X	X	X	X
SUBEXIT Subroutine EXIT statement	–	X	X	–	–
WHILE/END Delimits a WHILE repeat loop		*	*	*	–

* Product performs function, using different command.

Table 13-1 (Cont.) BASIC Language Features—PDP-11

	ANSI Minimal	BASIC +2 RSTS	BASIC +2 RSX	BASIC -PLUS	BASIC -11 RT-11
Event and Error Handling Statements					
CTRLC					
Enable ^C trapping	—	X	X	*	X
RCTRLC					
Disable ^C trapping	—	X	X	*	X
ERL					
Line number where error occurred	—	X	X	X	—
ERN$					
Module name with error	—	X	X	—	—
ERR					
Code for most recent error	—	X	X	X	—
ERT$(N)					
Returns text string for ERR-n	—	X	X	*	—
EXTYPE					
HANDLER use: exception code	—	*	*	*	—
ON ERROR GOTO					
Establishes an error handler	—	X	X	X	—
ON ERROR GOTO 0					
Disables error handling	—	X	X	X	—
ON..GOBACK					
Error exit to calling routine	—	X	X	—	—
RESUME [NNNNN]					
Ends an error handling routine	—	X	X	X	—
Matrix Manipulation Statements					
MAT A = CON(EXP)					
Assigns result of exp to elements of a	—	X	X	X	—
MAT A = IDN(M,N)					
Assigns identity matrix for (M x N) to al	—	X	X	X	—
MAT INPUT [#n]v..					
Matrix INPUT	—	X	X	X	—
MAT LET al=expr					
Matrix assignment	—	X	X	X	—
MAT LINPUT [#]v..					
Matrix string input	—	X	X	—	—
MAT PRINT [#N] v					
Matrix PRINT	—	X	X	X	—
MAT READ v,v...					
Matrix READ	—	X	X	X	—
MAT al = TRN(a2)					
Matrix transpose of a2, assigned to al	—	X	X	X	—

*Product performs function, using different command.

Table 13-1 (Cont.) BASIC Language Features—PDP-11

	ANSI Minimal	BASIC +2 RSTS	BASIC +2 RSX	BASIC -PLUS	BASIC -11 RT-11
Matrix Manipulation Statements (Continued)					
MAT a1 = ZER Sets elements of a1 to zero	—	X	X	X	—
MAT a1$ = NUL$ Elements of a1$ set to null string	—	X	X	—	—
MAT expressions MAT arr1 = arr2 [+, −, *] arr3	—	X	X	X	—
Input/Output Statements					
Block I/O Block I/O (random access)	—	X	X	X	—
CLOSE [#N,...] CLOSE all files, or a single specified file	—	X	X	X	X
DECIMAL KEYS Indexed file access and update	—	—	—	—	—
DELETE Record deletion	—	X	X	—	—
ECHO #N Enable input echo on #n	—	*	*	—	—
FIELD #N,... Organizes a random file buffer into fields	—	X	X	X	—
FIND Record I/O FIND	—	X	X	X[1]	—
GET Record GET	—	X	X	X[1]	—
INPUT "SS", list Prompts for INPUT with SS (any length literal)	—	X	X	X	—
INPUT #B, list INPUTs from disk unit b.	—	X	X	X	X
INPUT <list> INPUTs data from the keyboard	X	X	X	X	X
Integer Keys Indexed File access and update	—	X	X	—	—
KILL "filespec" Deletes a disk file	—	X	X	X	X
LINPUT #N, A$ Input a line from file #n	—	X	X	X	X
LINPUT ["S",]A$ Input a line, excluding terminating CR/LF/...	—	X	X	X	X

* Product performs function, using different command.
1 RSTS/E native files only.

Table 13-1 (Cont.) BASIC Language Features—PDP-11

	ANSI Minimal	BASIC +2 RSTS	BASIC +2 RSX	BASIC -PLUS	BASIC -11 RT-11
Input/Output Statements (Continued)					
MOVE TO/FROM					
Item pack/unpack in record I/O	—	X	X	—	—
NAME A$ AS B$					
Renames a data file	—	X	X	X	X
NOECHO #N					
Disable input echo, ch #n	—	*	*	—	X
OPEN ...					
Opens file, assigns mode and buffer	—	X	X	X	—
OPEN VIRTUAL					
Virtual (disk) array	—	X	X	1	*
PRINT #B,list					
Write data to sequential file buffer	—	X	X	X	X
PRINT #F USING..					
Formatted sequential write to disk	—	X	X	X	X
PRINT TAB(N),...					
Move cursor right to specified TAB position	X	X	X	X	X
PRINT USING A$..					
Prints formatted value(s) on screen	—	X	X	X	X
PRINT list					
Prints item(s) at current cursor position	X	X	X	X	X
PUT					
Record PUT	—	X	X	X[1]	—
PUT #N					
Move data from file buffer to random access disk	—	X	X	X[1]	—
READ list					
READs value from a DATA statement	X	X	X	X	X
RESTORE					
Resets pointer to first item of first DATA	X	X	X	X	X
RESTORE #N					
Restore/Rewind file		X	X	—	X
RFA Access					
Direct (record file address) access to indexed, sequential, or relative file	—	X	X	—	—
Record locking					
Explicit record locking	—	X	X	*	—

* Product performs function, using different command.
1 RSTS/E native files only.

Table 13-1 (Cont.) **BASIC Language Features—PDP-11**

	ANSI Minimal	BASIC +2 RSTS	BASIC +2 RSX	BASIC -PLUS	BASIC -11 RT-11
Input/Output Statements (Continued)					
SCRATCH Truncate a file	—	X	X	—	—
SLEEP N Wait n seconds, resume	—	X	X	X	—
Segmented Keys Indexed File Access and Update	—	X	X	—	—
UNSAVE filespec Deletes program on disk	—	*	*	*	X
UPDATE Record update	—	X	X	—	—
USEROPEN xxx Invoke xxx at OPEN to fill in file attributes	—	X	X	—	—
WAIT N Set N seconds input timeout	—	X	X	X	—
WIDTH NNN Sets printed line width for PRINT (or LPRINT)	—	—	—	—	*
Program Debugging Statements					
BREAK 100 Set break points in a program	—	X	X	—	—
CONT Continues execution after STOP/BREAK	—	X	X	X	—
TROFF Turns off the program trace function	—	—	—	—	—
TRON Turns on the program trace function	—	—	—	—	—
UNBREAK Remove breakpoint set by the BREAK command	—	X	X	—	—
Program Preparation Statements and Commands					
APPEND F Add file text to end of program in memory	—	X	X	X	*
AUTO [ST [,INC]] Numbers lines automatically	—	*	*	—	—
CAT [file] List file(s) available for use	—	*	*	X	—

* Program performs function, using different command.

Table 13-1 (Cont.) BASIC Language Features—PDP-11

	ANSI Minimal	BASIC +2 RSTS	BASIC +2 RSX	BASIC -PLUS	BASIC -11 RT-11
Program Preparation Statements and Commands (Continued)					
COMPILE					
Compile program, do checks, don't RUN	—	X	X	X	X
Cross reference					
Compiler produces cross-ref listing	—	X	X	*	—
DELETE M [−N]					
Erases program lines from memory	—	X	X	X	X
EDIT					
Puts user into EDT with program loaded	—	—	—	—	—
EDIT [N]					
Puts computer into edit mode for specified line	—	X	X	—	*
ERASE					
Deletes an array (+ or a program). See SCRATCH, also	—	*	*	—	*
Flag DECLINING					
Flag use of obsolete/non-transportable syntax	—	X	X	—	—
HELP/INQ					
Print HELP for topic	—	X	X	—	—
Immediate Mode					
Direct execution of unnumbered BASIC line	—	X	X	X	X
LIST					
List program lines to terminal	—	X	X	X	X
LIST M [−N]					
List program line(s) M [to N]	—	X	X	X	X
LISTNH					
List, print no heading	—	X	X	X	X
LOAD filespec					
Load precompiled program file from disk	—	X	X	—	—
NEW [name]					
Erase program from memory, initialize variables	—	X	X	X	X
OLD name					
Bring program from disk to memory	—	X	X	X	X
Opt/Line Nums					
Line numbers are generally optional		X	X	*	—

* Program performs function, using different command.

Table 13-1 (Cont.) BASIC Language Features—PDP-11

	ANSI Minimal	BASIC +2 RSTS	BASIC +2 RSX	BASIC -PLUS	BASIC -11 RT-11
Program Preparation Statements and Commands (Continued)					
RENAME name New name for program in memory	—	X	X	X	X
REPLACE [name] Write program in memory onto disk	—	X	X	X	X
RESEQUENCE ... Renumbers a program. (See RENUMBER)	—	*	*	—	X
RUN Execute resident program	—	X	X	X	X
RUN file Loads and executes specified disk program	—	X	X	X	X
RUNNH ... RUN, print no heading	—	X	X	X	X
SAVE [file] Saves the BASIC program on disk	—	X	X	X	X
SEQUENCE N [,1] Generate line numbers	—	X	X	—	—
SET xxxx Turn compiler/environment options on or off	—	X	X	—	—
Source Listing Compiler produces listings with source and error messages	—	X	X	—	—
Subset Flagger /BP2 puts you in BASIC-PLUS-2 subset of VAX BASIC	—	—	—	—	—
ANSI flagger /ANSI checks ANSI minimal conformance	—	—	—	—	—
line-by-line syntax check /SYNTAX causes each line to be checked as it is entered	—	X	X	—	—
/VARIANT allows conditional compilation on user supplied value					

* Program performs function, using different command.

Table 13-1 (Cont.) BASIC Language Features—PDP-11

	ANSI Minimal	BASIC +2 RSTS	BASIC +2 RSX	BASIC -PLUS	BASIC -11 RT-11
Directives to the BASIC System					
%ABORT <text> (See %IP), stop compilation immediately	—	X	X	—	—
%CROSS Enable cross reference, in program listing	—	X	X	—	—
%IDENT <name> Program id, goes in .OBJ file as well as listing file	—	X	X	—	—
%IF <cond> %THEN Conditional compilation of source text	—	X	X	—	—
%INCLUDE — %CDD INCLUDE from a Common Data Dictionary	—	—	—	—	—
%INCLUDE Directive—inserts text from <file>	—	X	X	—	—
%LET Allows assignments to lexical variables	—	X	X	—	—
%LIST Directive—enables compiler listing	—	X	X	—	—
%NOCROSS Disable cross reference, in program listing	—	X	X	—	—
%NOLIST Directive—disables compiler listing	—	X	X	—	—
%SBTTL <text> Subtitle (line 2) for listing pages	—	X	X	—	—
%TITLE <text> Title text for line 1 of listing pages	—	X	X	—	—
%VARIANT Returns user-supplied /VARIANT value	—	X	X	—	—
BRLRES filespec Selects BASIC resident library	—	X	X	—	—
CLEAR CLEARs all variables and program (SCRATCH)	—	*	*	X	X
Compiler Generates object code	—	X	X	—	—
DSKLIB F Selects disk library/link	—	X	X	—	—

* Product performs functions, using different commands.

Table 13-1 (Cont.) BASIC Language Features—PDP-11

	ANSI Minimal	BASIC +2 RSTS	BASIC +2 RSX	BASIC -PLUS	BASIC -11 RT-11
Directives to the BASIC System (Continued)					
IDENTIFY Print compiler ID line	—	X	X	—	—
LIBR filespec Select shared runtime library	—	X	X	—	—
LOCK/sw/sw.. Set BUILD/COM switches	—	X	X	—	—
ODLRMS filespec Select RMS library/link	—	X	X	—	—
OVERLAY ... BASIC-11 segmentation	—	—	—	—	X
RMSRES filespec Select RMS shared resident library	—	X	X	—	—
SCALE N Set floating point scale factor (0–6)	—	X	X	X	—
SCRATCH Reinitializes BASIC memory (see CLEAR, NEW also)		X	X	*	X
SHOW Print present defaults		X	X	—	—
Miscellaneous Statements					
CHANGE X$ TO Y String characters to array cells	—	X	X	X	—
CHANGE Y TO X$ Change array cells -> string characters	—	X	X	X	—
POKE adr,value Puts a value into RAM memory	—	*	*	—	—
RANDOM[IZE] (Re)seeds random number generator	X	X	X	X	X
REM Starts REMARK, goes to <eol>	X	X	X	X	X

* Product performs function, using different command.


COBOL

Chapter 14

COBOL

COBOL-81 Offers Ease of Use for Business Applications.

COBOL, the COmmon Business Oriented Language,is a high-level,industry-wide data processing language that has been designed specifically for business applications such as payroll, inventory control, and accounts receivable.

Digital's COBOL for the PDP-11 family is COBOL-81,Version 2, which is based on the ANSI-74 COBOL standard (X3.23-1974) and has been validated by the U.S. Government's Federal Compiler Testing Center. COBOL-81 runs on systems ranging in size from the MICRO/PDP-11 and PDP-11/23 through the PDP-11/70. COBOL-81 is also available on Digital's Professional 300 series of personal computers when used in conjunction with the Professional Tool Kit.

COBOL-81 is a fully featured COBOL with mainframe-like performance, and is designed for Micro/RSX, RSX-11M-PLUS, RSX-11M, and RSTS/E business systems. It includes various Digital extensions to COBOL, including screen handling at the source language level. By fully utilizing the Commercial Instruction Set (CIS), COBOL-81 produces compact, high-performance programs.

COBOL-81 is a subset of VAX-11 COBOL and shares a common syntax. Programs written for COBOL-81 can be compiled and executed using VAX-11 COBOL without source changes, giving entry-level users and other customers a migration path from the smallest PDP-11 systems to the largest VAX/VMS systems. This compatibility is important to the increasing number of customers who combine VAX and PDP-11 systems to meet their business needs.

VAX-11 has a COBOL-81 subset flagger, ideal for those who use both VAX and PDP-11 systems. You can write, debug, and run code, using the performance and tools of a VAX, and then run your program through the COBOL-81 subset flagger. Once no error flags appear, you can move your source code and recompile it on a PDP-11.

For PDP-11 users who may eventually want to upgrade to a VAX, COBOL-81 has a VAX-11 COBOL flagger, which points out any problems that may arise in migration to a VAX.

COBOL-81 Makes Programming More Productive.

COBOL-81 provides features that are aimed at making COBOL programs and programmers highly productive. COBOL programmers may be used to working with batch-mode COBOL on large machines, but COBOL-81 was designed with interactive features familiar to Digital customers and small computer users. For example:

- Source code may be entered by using one of the many text editors available on the PDP-11. The Digital terminal format files created by these editors are also shorter than ANSI format files and help save disk space and compile-time processing, very critical features on systems with limited disk space and processor power.
- Debugging can be handled interactively, allowing for error-free program development.
- The Build Overlay Description Language (BLDODL) utility offers a simplified way of structuring segmented programs or subprograms into efficient task images.

With COBOL-81, programmers have the tools needed for interactive video data processing on VT100 series and VT52 video terminals, as well as the Professional 300 series of personal computers.

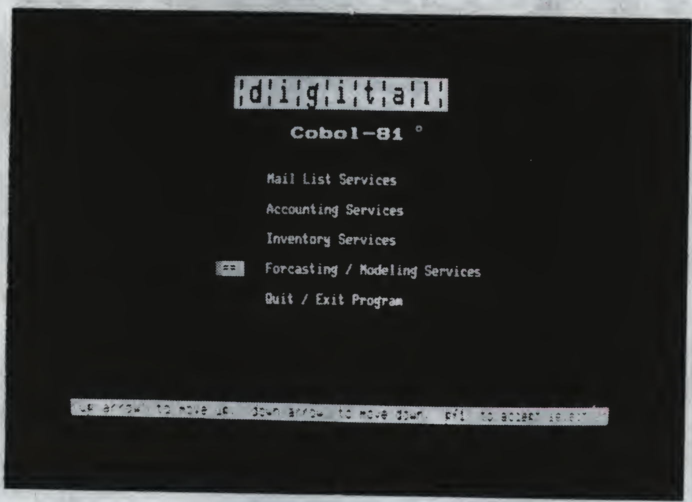
The DISPLAY statement positions the cursor at any row or column on the screen, converts any valid COBOL data type to a format suitable for screen display, and makes the terminal beep to alert the user. It also controls many of the VT100-series Advanced Video Option features such as bolding, blinking, underlining, and reverse video. It can erase the entire screen, the entire line, or everything from the cursor to the end of the line or the bottom of the screen.

The ACCEPT statement lets the programmer input information, define fixed-field widths, right-or left-justify data, and convert screen-format text into any valid COBOL data type. ACCEPT also can prevent data from appearing on the screen for security purposes, lets you specify default values, and lets you define special function keys and the auxiliary keypad. ACCEPT controls the same VT100 Advanced Video Option features as does the DISPLAY statement.

COBOL-81 Measures Up to the Standards.

COBOL-81 is ANSI-standard COBOL, rather than a small subset of the ANSI standard, as found on many other small systems. It also has features currently being recommended for the next ANSI COBOL standard, assuring future transportability of software.

COBOL-81 meets high-level requirements on many modules as described by FIPS PUB21-1. These modules and requirements are shown below.



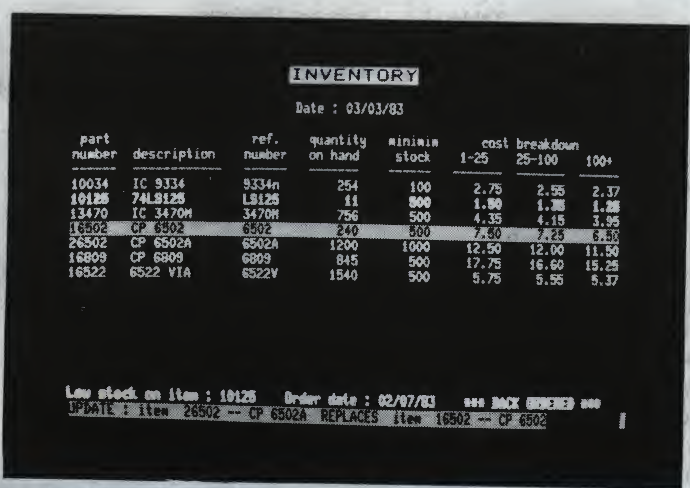


Figure 14-1 Screen Formats

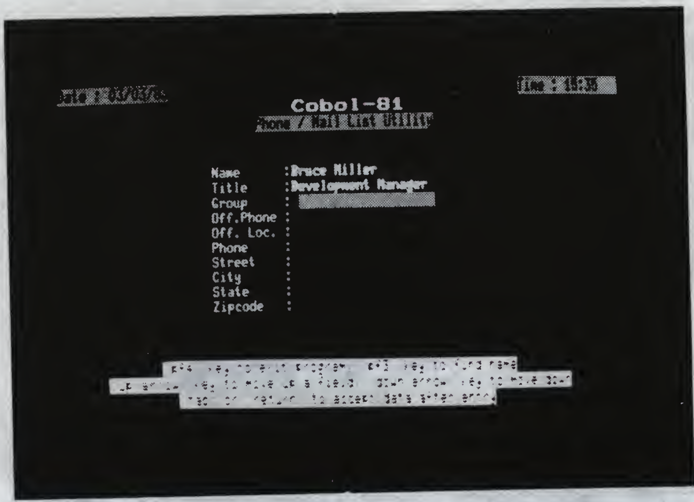


Figure 14-1 Screen Formats (Cont.)

Table 14-1 Language Features

ANSI Module	LEVEL Supported By COBOL-81	FIPS PUB21-1 Requirements For High Level
Nucleus	2[1]	2
Table Handling	2	2
Sequential I/O	2	2
Relative I/O	2	2
Indexed I/O	2	2
Segmentation	2[2]	2
Library	1[3]	2
Debug	—[4]	2
Interprogram Communication	1	2
SORT/MERGE	2	2
Communication	—	2

[1] The nucleus module complies at level 2, except that the ALTER statement and ALPHABET IS literal clause are not included.

[2] The segmentation module complies at Level 2, except that independent segments from Level 1 are not included.

[3] The library module includes a partial Level 2 REPLACING facility.

[4] COBOL-81 uses an interactive symbolic debugger, which may be substituted for the Debug module at all but the high level.

COBOL-81 Can Be Installed By the Customer.

COBOL-81 has been designed so that customers can install the software without requiring the aid of a Digital software specialist. The installation procedure determines a default compiler for the user's hardware configuration. If the compiler is acceptable to the user (indicated by a yes response to questions from the system), the default compiler is then built. If, however, the compiler is not acceptable, the system prompts the user with several more questions in order to build a customized compiler.

The compiler performance is impressive; it compiles at speeds ranging up to 700 lines and more per minute on a PDP-11/44. Because the compiler is designed for the Commercial Instruction Set (CIS), it generates compact high-performance object code, resulting in highly productive applications. This design also requires less use of time-consuming overlays.

COBOL-81 Performs on the Benchmarks that Count.

On a host of industry-standard benchmarks, COBOL-81 has shown its great speed. Typical of the results are the figures from USSTEEL, a nationally known, widely referenced synthetic benchmark developed by U.S. Steel Corporation. Tests run of USSTEEL on a PDP-11/44 system with the optional Commercial Instruction Set (CIS) gave COBOL-81 a productivity index rivaling COBOL languages on machines of much greater size and cost.

COBOL-81 performs so well because its compiler was built for fast compilation and program execution. It takes advantage of the CIS hardware to enhance performance in data movement and packed-decimal arithmetic. Using CIS also results in memory-efficient object code and reduces the need for time-consuming overlays. Even without use of CIS, COBOL-81 performance is excellent.

COBOL-81 also supports cluster and resident libraries. These libraries decrease disk storage requirements for task images, increase the user's task area, increase taskbuilder performance, and increase memory availability in a multiuser environment.

COBOL-81 Facilities Make Your Job Easier.

COBOL-81 provides facilities for processing sequential, relative, and indexed files. These include character string facilities, a CALL facility, SORT/MERGE, and library facilities.

Character String Facilities

COBOL-81 provides INSPECT, STRING, and UNSTRING verbs for easy handling of textual data. Using these verbs, programmers can count and/or replace embedded character strings and can join together or break out separate strings with various delimiters.

CALL Facility

The CALL facility allows COBOL programs to invoke separately compiled subprograms written in COBOL-81 or MACRO-11 Assembly language. The CALL statement is used to execute routines that are external to the source file in which the CALL statement appears. This allows for greater flexibility of modular program development, permits functional specifications of small, well-defined source modules, and gives access to operating system-dependent features via sub-routines written in MACRO-11.

The CALL statement facility has been extended by allowing the user to pass arguments BY REFERENCE (the default in COBOL) and BY DESCRIPTOR.

SORT/MERGE

The SORT/MERGE facility provides the SORT and MERGE verbs for record and file sorting and merging capabilities. Sorting can be specified by multiple keys in either ascending or descending order. Organizations of the input files can be totally independent.

Library Facilities

COBOL-81 supports a full Level 1 ANSI-74 library facility and partial Level 2 replacing facility. All frequently used data descriptions and program text sections can be stored in library files that are available to all programs. The library files can be copied at compile time to reduce program preparation time and to eliminate a common source of error during program development.

The Symbolic Interactive Debugger Allows Faster, Error-free Program Development.

With COBOL-81's easy-to-learn, easy-to-use interactive debugger, programmers can debug programs by including the debugger when taskbuilding the program, rather than having to alter the source program during testing. Programmers can follow the program flow during the execution of a job.

With the debugger, the programmer can:

- Reference data items by their user-defined names
- Reference section names and paragraph names
- Examine and modify the value of variables during program execution
- Optionally stop and restart programs at the line numbers, section name or paragraph name specified by the programmer
- Gain control at program commencement and at abnormal termination

Other Debugging Features

To make program debugging even easier, the COBOL-81 compiler produces source listings with embedded English diagnostics. Fully descriptive diagnostic messages are listed at the point of error. Many error conditions, varying from simple warnings to fatal error detections, are checked at compile-time.

When an error occurs during execution, the type of error, program name, and line number of the source statement that caused the error are displayed on the user's terminal. If the program is executing with an active PERFORM, the line numbers of the active PERFORM statements will be produced on the user's terminal. When the error is detected during execution of a subprogram, a backwards trace of the calling programs that were active at the time of the error is produced on the user's terminal.

The compiler provides the option of specifying data division and procedure division allocation maps and a cross-reference listing. The cross-reference listing is a listing of all data names, procedure names, and the sourceline numbers of those program lines containing the definitions and references. For each name, a list of ordered sourceline numbers is displayed. Sourceline numbers for defined items are distinguished from sourceline numbers for referenced items.

Source Program Formats

The COBOL-81 compiler accepts source programs that are coded using either the ANSI-standard format files or shorter, easy-to-enter Digital terminal format files. Terminal format files are designed for use with interactive text editors. They eliminate the line numbers and identification fields and allow the user to enter horizontal tab characters and short text lines. Terminal format files also help save disk space and compiletime processing, very critical features on small systems with limited disk space and processor power.

Utility Programs

COBOL-81 provides the REFORMAT and BLDODL utilities to aid the user in data processing.

The REFORMAT utility reads COBOL source programs that are coded using Digital terminal format and converts the source statements to the ANSI-standard format accepted by other COBOL compilers throughout the industry. It also has the inverse option to accept programs written in ANSI-standard format and convert the source statements to Digital terminal format. This offers the advantage of saving disk space and compile-time processing when a user is initially migrating from a non-Digital COBOL system to COBOL-81.

The BLDODL (Build Overlay Description Language) utility combines skeleton overlay description files generated by COBOL compilations into a single ODL file for use by the taskbuilder. This utility allows the user a simplified way of structuring segmented programs or subprograms into an efficient task image.

Commercial Instruction Set (CIS)

COBOL-81 takes full advantage of CIS to enhance performance in data movement and packed-decimal arithmetic. CIS increases processing so that COBOL-81 applications run about 2.5 times faster than without CIS. Using CIS also provides the added benefit of compact object code, reducing the requirement for time-consuming overlays.

Table 14-2 COBOL Language Features

Features	Implementation Level and Module Code		ANSI-74 X3.23	COBOL-81 V2
LANGUAGE CONCEPTS				
Character Set				
Characters used for words				
0,1,...,9 A,B,...,Z	1	NUC	X	X
- (hyphen or minus sign)				
a,b,...,z		EXT	—	X
Punctuation characters				
. " ( ) space or blank	1	NUC	X	X
=	1	NUC	X	—
, ;	2	NUC	X	X
' (single quote)		EXT	—	—
Characters used in arithmetic operations				
+ - * / **	2	NUC	X	X
Characters used in relations				
< > =	2	NUC	X	X
Characters used in editing				
B O + - CR DB * $. ,	1	NUC	X	X
/	1	NUC	X	X
Separators				
Semicolon and comma not permitted	1	NUC	X	—
Semicolon and comma allowed	2	NUC	X	X
	1	(ANS-82)		
Character strings	1	NUC	X	X
COBOL words	1	NUC	X	X
Maximum 30 characters			X	X
Maximum 31 characters		EXT	—	—
User-defined words	1	NUC	X	X
cd-name	1	COM	X	—
condition-name	2	NUC	X	X
data-name (first char. must be alphabetic)	1	NUC	X	—
alphabet-name	1	NUC		X
area-name		DBM	—	—
data-name (need not begin alphabetic)	2	NUC	X	X
file-name	1	SEQ	X	X
index-name	1	TBL	X	X
keepLIST-name		DBM	—	—
level-number	1	NUC	X	X

Table 14-2 (Cont.) COBOL Language Features

Features	Implementation Level and Module Code		ANSI-74 X3.23	COBOL-81 V2
LANGUAGE CONCEPTS				
Character Set (Continued)				
library-name	2	LIB	X	—
mnemonic-name	1	NUC	X	—
paragraph-name	1	NUC	X	X
program-name	1	NUC	X	X
realm-name		DBM	—	—
record-name	1	NUC	X	X
report-name	1	RPW	X	—
routine-name (may be omitted)	1	NUC	X	—
schema-name		DBM	—	—
section-name	1	NUC	X	X
segment number	1	SEG	X	X
set-name		DBM	—	—
subschema-name		DBM	—	—
symbolic character				—
text-name	1	LIB	X	X
System names	1	NUC	X	X
computer-name	1	NUC	X	X
implementor name	1	NUC	X	X
language-name (may be omitted)	1	NUC	X	—
Reserved words	1	NUC	X	X
Key words	1	NUC	X	X
Optional words	1	NUC	X	X
Connectives				
qualifiers: OF IN	2	NUC	X	X
series: comma, semicolon	2	NUC	X	X
logical: AND, OR, AND NOT, OR NOT	2	NUC	X	X
Special registers				
LINE-COUNTER, PAGE-COUNTER	1	RPW	X	—
LINAGE-COUNTER	2	SEQ	X	X
DEBUG-ITEM	1	DEB	X	—
TALLY	1	NUC	—	—
DB-CONDITION		DBM	—	—
DB-CURRENT-RECORD-ID		DBM	—	—
DB-CURRENT-RECORD-NAME		DBM	—	—
RMS-STS		EXT	—	X
RMS-STV		EXT	—	X
RMS-FILENAME		EXT	—	—

Table 14-2 (Cont.) COBOL Language Features

Features	Implementation Level and Module Code		ANSI-74 X3.23	COBOL-81 V2
LANGUAGE CONCEPTS				
Character Set (Continued)				
Figurative constants				
ZERO	1	NUC	X	X
ZEROS, ZEROES	2	NUC	X	X
SPACE	1	NUC	X	X
SPACES	2	NUC	X	X
HIGH-VALUE, LOW-VALUE	1	NUC	X	X
HIGH-VALUES, LOW-VALUES	2	NUC	X	X
QUOTE	1	NUC	X	X
QUOTES	2	NUC	X	X
ALL literal	2	NUC	X	X
Special character words				
Arithmetic operators	2	NUC	X	X
Relation operators	2	NUC	X	X
Literals	1	NUC	X	X
Nonnumeric literals have lengths from 1 through at least 120 chars	1	NUC	X	X
at least 256 chars		EXT	—	X
Quote character within nonnumeric literals			X	X
Numeric literals have lengths from 1 through at least 18 digits			X	X
PICTURE character strings	1	NUC	X	X
Comment entries	1	NUC	X	X
Picture char. string up to 255 characters		EXT	—	—
Qualification				
No qualification permitted	1	NUC	X	—
Qualification permitted	2	NUC	X	X
Subscripting to 3 levels	1	TBL	X	X
Subscripting to 48 levels	2	TBL	—	—
Indexing to 3 levels	1	TBL	X	X
Indexing to 48 levels	2	TBL	—	—
Source Program Structure				
Nested Source Programs	2	IPL	—	—

Table 14-2 (Cont.) COBOL Language Features

Features	Implementation Level and Module Code		ANSI-74 X3.23	COBOL-81 V2
IDENTIFICATION DIVISION				
The PROGRAM-ID Paragraph	1	NUC	X	X
INITIAL clause	2	IPC	–	–
COMMON clause	2	IPC	–	–
The AUTHOR Paragraph	1	NUC	X	X
The INSTALLATION Paragraph	1	NUC	X	X
The DATE-WRITTEN Paragraph	1	NUC	X	X
The DATE-COMPILED Paragraph	2	NUC	X	X
The SECURITY Paragraph	1	NUC	X	X
The REMARKS Paragraph	1	NUC	–	–
ENVIRONMENT DIVISION				
entire division may be omitted				X
Configuration Section				
Entire section may be omitted		EXT	–	X
The SOURCE-COMPUTER Paragraph				
computer-name	1	NUC	X	X
WITH DEBUGGING MODE phrase	1	DEB	X	–
The OBJECT-COMPUTER Paragraph				
computer-name	1	NUC	X	X
MEMORY-SIZE clause	1	NUC	X	X
PROGRAM-COLLATING SEQUENCE clause	1	NUC	X	X
SEGMENT-LIMIT clause	2	SEG	X	X
The SPECIAL-NAMES Paragraph				
Implementor-name IS mnemonic-name	1	NUC	X	X
ON STATUS	1	NUC	X	X
OFF STATUS	1	NUC	X	X
Implementor-name series	1	NUC	X	X
alphabet-name clause	1	NUC	X	X
STANDARD-1	1	NUC	X	X
STANDARD-2	1	NUC	–	–
NATIVE	1	NUC	X	X
Implementor-name	1	NUC	X	–
literal	2	NUC	X	–
CURRENCY-SIGN clause	1	NUC	X	X
DECIMAL-POINT clause	1	NUC	X	X
SYMBOLIC CHARACTER	2	NUC	–	–

Table 14-2 (Cont.) COBOL Language Features

Features	Implementation Level and Module Code		ANSI-74 X3.23	COBOL-81 V2
ENVIRONMENT DIVISION				
Input-Output Section				
The FILE-CONTROL Paragraph				
SELECT	1	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
	1	SRT	X	X
OPTIONAL	2	SEQ	X	X
ASSIGN-TO implementor name	1	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
	1	SRT	X	X
MULTIPLE REEL/UNIT	1	SEQ	—	—
	1	SRT	—	—
RESERVE integer AREA(S)	2	SEQ	X	X
	2	REL	—	X
	2	INX	—	X
FILE-LIMIT literal THRU literal	1	SEQ	—	—
	1	REL	—	—
literal series	2	SEQ	—	—
	2	REL	—	—
data-name THRU data-name	2	SEQ	—	—
	2	REL	—	—
data-name series	2	SEQ	—	—
	2	REL	—	—
ORGANIZATION				
SEQUENTIAL	1	SEQ	X	X
RELATIVE	1	REL	X	X
INDEXED	1	INX	X	X
ACCESS MODE				
SEQUENTIAL	1	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
RANDOM	1	REL	X	X
	1	INX	X	X
DYNAMIC	2	REL	X	X
	2	INX	X	X
PROCESSING MODE SEQUENTIAL	1	SEQ	—	—
	1	REL	—	—
ACTUAL KEY	1	REL	—	—

Table 14-2 (Cont.) COBOL Language Features

Features	Implementation Level and Module Code		ANSI-74 X3.23	COBOL-81 V2
ENVIRONMENT DIVISION				
Input-Output Section (Continued)				
RECORDING MODE clause	1	EXT	—	—
RELATIVE KEY	1	REL	X	X
RECORD KEY	1	INX	X	X
SYMBOLIC KEY		EXT	—	—
ALTERNATE RECORD KEY	2	INX	X	X
FILE STATUS clause	1	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
The I/O CONTROL Paragraph				
RERUN	1	SEQ	X	1[1]
	1	REL	X	1
	1	INX	X	1
SAME AREA	1	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
SAME RECORD AREA	2	SEQ	X	X
	2	REL	X	X
	2	INX	X	X
	2	SRT	X	X
SAME SORT/SORT MERGE AREA clause	2	SRT	X	X
SAME series	1	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
MULTIPLE FILE TAPES	2	SEQ	X	—
APPLY clause		EXT	—	X
Print-Control		EXT	—	X
Extension		EXT	—	X
Fill-Size		EXT	—	X
Mass-Insert		EXT	—	X
Contiguous		EXT	—	X
Window		EXT	—	X

1 Supported for documentation purposes only.

Table 14-2 (Cont.) COBOL Language Features

Features	Implementation Level and Module Code		ANSI-74 X3.23	COBOL-81 V2
DATA DIVISION				
entire division may be omitted			—	X
Sections				
Communication Section	1	COM	X	—
File Section	1	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
	1	SRT	X	X
	1	RPW	X	—
Linkage Section	1	IPC	X	X
Working-Storage Section	1	NUC	X	X
Report Section	1	RPW	X	—
Subschema Section		DBM	—	—
Schema Section		DBM	—	—
Description Entries				
Communication description entry	1	COM	X	—
Data description entry	1	NUC	X	X
File description entry	1	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
	1	RPW	X	—
Record description entry	1	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
Sort-merge description entry	1	SRT	X	X
Report description	1	RPW	X	—
Report group description entry	1	RPW	X	—
Subschema description entry		DBM	—	—
Keeplist description entry		DBM	—	—
Clauses				
BLANK WHEN ZERO clause	1	NUC	X	X
BLOCK CONTAINS clause integer CHARACTERS/RECORDS	1	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
	1	RPW	X	—

Table 14-2 (Cont.) COBOL Language Features

Features	Implementation Level and Module Code		ANSI-74 X3.23	COBOL-81 V2
DATA DIVISION				
Clauses (Continued)				
integer-1 TO integer-2	2	SEQ	X	1 [1]
	2	REL	X	1 [1]
	2	INX	X	1 [1]
	1	RPW	X	—
CODE clause	1	RPW	X	—
CODE-SET clause	1	SEQ	X	X
	1	RPW	X	—
COLUMN NUMBER clause	1	RPW	X	—
CONTROL clause	1	RPW	X	—
data-name clause	1	NUC	X	X
	1	RPW	X	—
DATA-RECORD clause	1	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
	1	SRT	X	X
EXTERNAL clause	2	IPC	—	—
FILLER	1	NUC	X	X
FILLER optional	1	NUC	—	X
GLOBAL clause	2	IPC	—	—
GROUP INDICATE clause	1	RPW	X	—
JUSTIFIED clause (JUST)	1	NUC	X	X
LABEL RECORDS clause				
STANDARD/OMITTED	1	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
	1	RPW	X	—
data-name	1	SEQ	—	—
data-name series	1	SEQ	—	—
LEVEL-NUMBER				
01 thru 10 (must be 2 digits)	1	NUC	X	—
1 thru 49 (may be one digit)	2	NUC	X	X
66	2	NUC	X	X
77	1	NUC	X	X
88	2	NUC	X	X
LINAGE CLAUSE	2	SEQ	X	X
OCCURS clause				
integer TIMES	1	TBL	X	X

1 Blocks are fixed length. Integer-1 is for documentation only.

Table 14-2 (Cont.) COBOL Language Features

Features	Implementation Level and Module Code		ANSI-74 X3.23	COBOL-81 V2
DATA DIVISION				
Clauses (Continued)				
ASCENDING/DESCENDING				
data-name	2	TBL	X	X
data-name series	2	TBL	X	X
INDEXED BY index-name	1	TBL	X	X
integer-1 TO integer-2				
DEPENDING ON data-name	2	TBL	X	X
PAGE clause	1	RPW	X	—
PICTURE clause				
Character string may contain				
30 characters	1	NUC	X	X
255 characters		EXT	—	—
Data characters: A X 9	1	NUC	X	X
Operational symbols: S V P	1	NUC	X	X
Fixed insertion chars:				
0 B , . $ + – CR DB	1	NUC	X	X
Fixed insertion char: /	1	NUC	X	X
Replacement or floating characters:				
$ + – Z *	1	NUC	X	X
Currency sign substitution	1	NUC	X	X
Decimal point substitution	1	NUC	X	X
RECORD CONTAINS clause	1	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
	1	SRT	X	X
	1	RPW	X	—
RECORD VARYING clause		SEG	—	X
		REL	—	X
		INX	—	X
		SRT	—	X
REDEFINES clause				
must not be nested	1	NUC	X	—
may be nested	2	NUC	X	X
RENAMES clause	2	NUC	X	X
REPORT clause	1	RPW	X	—

Table 14-2 (Cont.) COBOL Language Features

Features	Implementation Level and Module Code		ANSI-74 X3.23	COBOL-81 V2
DATA DIVISION				
Clauses (Continued)				
SIGN clause	1	NUC	X	X
SOURCE clause	1	RPW	X	—
SUM clause	1	RPW	X	—
SYNCHRONIZED clause (SYNC)	1	NUC	X	X
TYPE clause	1	RPW	X	—
USAGE clause				
COMPUTATIONAL (COMP; means binary)	1	NUC	X	X
COMP-1 (floating point)		EXT	—	—
COMP-2 (double precision floating point)		EXT	—	—
DISPLAY	1	NUC	X	X
DISPLAY-6 (SIXBIT)		EXT	—	—
DISPLAY-7 (ASCII)		EXT	—	—
DISPLAY-9 (EBCDIC)		EXT	—	—
INDEX	1	TBL	X	X
DATABASE-KEY		DBM	—	—
COMP-6		EXT	—	—
COMP-3 (packed decimal)		EXT	—	X
VALUE clause				
literal	1	NUC	X	X
literal series	2	NUC	X	—
literal THRU literal	2	NUC	X	—
literal range series	2	NUC	X	—
is EXTERNAL		EXT	—	—
is REFERENCE		EXT	—	—
VALUE of clause				
implementor-name IS literal	1	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
	1	RPW	X	—
implementor-name IS data-name	2	SEQ	X	X
	2	REL	X	X
	2	INX	X	X
	2	RPW	X	—

Table 14-2 (Cont.) COBOL Language Features

Features	Implementation Level and Module Code		ANSI-74 X3.23	COBOL-81 V2
PROCEDURE DIVISION				
entire division may be omitted	1	NUC	—	X
USING phrase in Procedure Division header	1	IPC	X	X
Declaratives	1	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
	1	RPW	X	—
	1	DEB	X	—
Arithmetic Expressions	2	NUC	X	X
Conditional Expressions	1	NUC	X	X
Simple conditions	1	NUC	X	X
Relation condition	1	NUC	X	X
Relational operators				
[NOT] GREATER THAN	1	NUC	X	X
[NOT] >	2	NUC	X	X
[NOT] LESS THAN	1	NUC	X	X
[NOT] <	2	NUC	X	X
[NOT] EQUAL TO	1	NUC	X	X
[NOT] =	2	NUC	X	X
EQUALS		EXT	—	X
Comparison				
Numeric operands	1	NUC	X	X
Nonnumeric operands				
Must be equal size	1	NUC	X	—
May be unequal size	2	NUC	X	X
Class conditions	1	NUC	X	X
NOT option	1	NUC	X	X
Switch-status condition	1	NUC	X	X
Condition-name condition	2	NUC	X	X
Data Base condition		DBM	—	—
Success condition		EXT	—	—
Sign condition	2	NUC	X	X
NOT option	2	NUC	X	X
Complex conditions				
Logical operators AND OR and NOT	2	NUC	X	X
Negated simple conditions	2	NUC	X	X
Combined and negated combined conditions	2	NUC	X	X

Table 14-2 (Cont.) COBOL Language Features

Features	Implementation Level and Module Code		ANSI-74 X3.23	COBOL-81 V2
PROCEDURE DIVISION				
Abbreviated combined relation condition	2	NUC	X	X
Statements				
Arithmetic statement				
Arithmetic operands limited to 18 digits	1	NUC	X	X
Overlapping Operands	1	NUC	X	X
	1	TBL	X	X
Multiple Results in Arithmetic statements	2	NUC	X	X
ACCEPT statement				
only one transfer of data	1	NUC	X	X
No restriction on number of transfers of data	2	NUC	X	—
AT END	1	EXT	—	—
END-ACCEPT	1	EXT	—	—
FROM	2	NUC	X	X
FROM DATE	2	NUC	X	X
FROM DAY	2	NUC	X	X
FROM DAY-OF-WEEK	2	NUC	—	—
FROM TIME	2	NUC	X	X
MESSAGE COUNT phrase	1	COM	X	—
ADD statement				
identifier/literal series	1	NUC	X	X
TO identifier	1	NUC	X	X
TO identifier series	2	NUC	X	X
GIVING identifier	1	NUC	X	X
GIVING identifier series	2	NUC	X	X
ROUNDED	1	NUC	X	X
SIZE ERROR	1	NUC	X	X
CORRESPONDING	2	NUC	X	X
END-ADD	1	NUC	—	—
ALTER statement				
procedure-name	1	NUC	X	—
procedure-name series	2	NUC	X	—
CALL statement				
literal	1	IPC	X	X
identifier	2	IPC	X	—
USING data-name	1	IPC	X	X

Table 14-2 (Cont.) COBOL Language Features

Features	Implementation Level and Module Code		ANSI-74 X3.23	COBOL-81 V2
PROCEDURE DIVISION				
Statements (Continued)				
by value		EXT	–	–
by descriptor		EXT	–	X
by reference	2	IPC	–	X
by content	2	IPC	–	–
ON OVERFLOW	2	IPC	X	–
END-CALL	2	IPC	–	–
CANCEL statement	2	IPC	X	–
CLOSE statement				
single file-name	1	SEQ	X	X
file-name series	2	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
REEL	1	SEQ	X	X
UNIT	1	SEQ	X	X
NO REWIND	2	SEQ	X	
LOCK	2	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
FOR REMOVAL	2	SEQ	X	X
WITH DELETE		EXT	–	–
		DBM	–	–
COMMIT statement		DBM	–	–
COMPUTE statement Identifier	2	NUC	X	X
Identifier series	2	NUC	X	X
END-COMPUTE	1	NUC	–	–
CONNECT		DBM	–	–
CONTINUE	1	NUC	–	–
DELETE statement	1	REL	X	X
	1	INX	X	X
		DBM	–	–
END-DELETE	1	REL/INX	–	–
DISCONNECT		DBM	–	–
DISABLE statement				
INPUT	1	COM	X	–
TERMINAL	2	COM	X	–
OUTPUT	1	COM	X	–
KEY identifier/literal	1	COM	X	–

Table 14-2 (Cont.) COBOL Language Features

Features	Implementation Level and Module Code		ANSI-74 X3.23	COBOL-81 V2
PROCEDURE DIVISION				
Statements (Continued)				
ENTER statement (may be omitted)	1	NUC	X	—
ENTRY statement		EXT	—	—
ERASE statement		DBM	—	—
EVALUATE	2	NUC	—	—
identifier/literal	2	NUC	—	—
arithmetic expression	2	NUC	—	—
conditional expression	2	NUC	—	—
TRUE/FALSE	2	NUC	—	—
when phrase	2	NUC	—	—
when other	2	NUC	—	—
END-EVALUATE	2	NUC	—	—
EXAMINE statement	1	NUC	—	—
EXIT statement	1	NUC	X	X
EXIT PROGRAM statement	1	IPC	X	X
FETCH statement		DBM	—	—
FIND statement		DBM	—	—
FREE statement	1	EXT/SEQ	—	—
	1	EXT/INX	—	—
	1	EXT/REL	—	—
		DBM	—	—
GENERATE statement	1	RPW	X	—
GET statement		DBM	—	—
GOBACK statement		EXT	—	—
GO TO statement				
TO optional	1	NUC	X	X
procedure-name required	1	NUC	X	X
procedure-name optional	2	NUC	X	—
DEPENDING ON phrase	1	NUC	X	X
IF statement				
Must be imperative statement	1	NUC	X	—
Nested statements	2	NUC	X	X
ELSE	1	NUC	X	X
		DBM	—	—
END-IF	1	NUC	—	—
INITIALIZE statement	2	NUC	—	—
identifier series	2	NUC	—	—
REPLACING	2	NUC	—	—

Table 14-2 (Cont.) COBOL Language Features

Features	Implementation Level and Module Code		ANSI-74 X3.23	COBOL-81 V2
PROCEDURE DIVISION				
Statements (Continued)				
INITIATE statement	1	RPW	X	—
INSERT statement		DBM	—	—
	1	NUC	X	—
INSPECT statement				
single character data item	1	NUC	X	X
multicharacter data item	2	NUC	X	X
INVOKE statement		DBM	—	—
KEEP statement		DBM	—	—
MERGE statement	2	SRT	X	X
MODIFY statement		DBM	—	—
MOVE statement				
TO identifier	1	NUC	X	X
identifier series	1	NUC	X	X
CORRESPONDING	2	NUC	X	X
		DBM	—	—
MULTIPLY statement				
BY identifier	1	NUC	X	X
BY identifier series	2	NUC	X	X
GIVING identifier	1	NUC	X	X
GIVING identifier series	2	NUC	X	X
ROUNDED	1	NUC	X	X
SIZE ERROR	1	NUC	X	X
END-MULTIPLY statement	1	NUC	—	—
NOTE sentence	1	NUC	—	—
OPEN statement				
ALLOWING statement				
ALL	1	EXT	—	X
READERS	1	EXT	—	X
WRITERS	1	EXT	—	—
UPDATERS	1	EXT	—	—
NONE	1	EXT	—	—
READ	1	EXT	—	—
REWRITE	1	EXT	—	—
WRITE	1	EXT	—	—
DELETE	1	EXT	—	—
ANY VERB	1	EXT	—	—

Table 14-2 (Cont.) COBOL Language Features

Features	Implementation Level and Module Code		ANSI-74 X3.23	COBOL-81 V2
PROCEDURE DIVISION				
Statements (Continued)				
INPUT				
Single file-name	1	SEQ	X	X
file-name series	2	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
REVERSED	2	SEQ	X	—
NO REWIND	2	SEQ	X	X
OUTPUT				
Single file-name	1	SEQ	X	X
file-name series	2	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
NO REWIND	2	SEQ	X	X
I-O				
Single file-name	1	SEQ	X	X
file-name series	2	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
EXTEND	2	SEQ	X	X
INPUT, OUTPUT, I-O and EXTEND series	2	SEQ	X	X
INPUT, OUTPUT and I-O series	1	SEQ	—	X
	1	REL	X	X
	1	INX	X	X
		DBM	—	—
PERFORM statement				
procedure-name	1	NUC	X	X
procedure-name optional	1	NUC	—	—
THRU	1	NUC	X	X
TIMES	1	NUC	X	X
UNTIL	2	NUC	X	X
VARYING	2	NUC	X	X
WITH TEST BEFORE/AFTER	1	NUC	—	—
END-PERFORM	1	NUC	—	—
READ statement				
file-name	1	SEQ	X	X
	1	REL	X	X

Table 14-2 (Cont.) COBOL Language Features

Features	Implementation Level and Module Code		ANSI-74 X3.23	COBOL-81 V2
PROCEDURE DIVISION				
Statements (Continued)				
	1	INX	X	X
INVALID KEY	1	REL	X	X
INTO identifier	1	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
NEXT	2	REL	X	X
AT END	1	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
KEY IS	2	INX	X	X
END-READ	1	SEQ/REL/INX	—	—
READY statement		DBM	—	—
RECEIVE statement				
MESSAGE	1	COM	X	—
SEGMENT	2	COM	X	—
INTO identifier	1	COM	X	—
NO DATA phrase	1	COM	X	—
RECONNECT statement		DBM	—	—
ROLLBACK statement		DBM	—	—
RELEASE statement				
record-name	1	SRT	X	X
FROM	1	SRT	X	X
RETAIN statement	1	EXT/SEQ	—	—
	1	EXT/INX	—	—
	1	EXT/REL	—	—
REMOVE statement		DBM	—	—
RETURN statement				
file-name	1	SRT	X	X
INTO	1	SRT	X	X
AT END	1	SRT	X	X
REWRITE statement				
FROM identifier	1	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
INVALID KEY phrase	1	REL	X	X
	1	INX	X	X
END-REWRITE	1	SEQ/REL/INX	—	—

Table 14-2 (Cont.) COBOL Language Features

Features	Implementation Level and Module Code		ANSI-74 X3.23	COBOL-81 V2
PROCEDURE DIVISION				
Statements (Continued)				
SEARCH statement	2	TBL	X	X
SEEK statement	1	REL	—	—
SEND statement				
FROM identifier	2	COM	X	—
FROM identifier WITH	1	COM	X	—
WITH identifier	2	COM	X	—
WITH EGI	1	COM	X	—
WITH EMI	1	COM	X	—
WITH EPI		EXT	—	—
BEFORE/AFTER ADVANCING	1	COM	X	—
SET statement	1	TBL	X	X
SORT statement				
Limited to one SORT, -STOP and I-O procedures	1	SRT	X	—
Program not limited- to one SORT	2	SRT	X	X
COLLATING SEQUENCE phrase	2	SRT	X	X
START statement	2	REL	X	X
	2	INX	X	X
STOP statement	1	NUC	X	X
STORE statement		DBM	—	—
STRING statement	2	NUC	X	X
SUBTRACT statement				
identifier/literal series	1	NUC	X	X
FROM	1	NUC	X	X
FROM series	2	NUC	X	X
GIVING identifier	1	NUC	X	X
GIVING identifier series	2	NUC	X	X
ROUNDED	1	NUC	X	X
SIZE ERROR	1	NUC	X	X
CORRESPONDING	2	NUC	X	X
END-SUBTRACT	1	NUC	—	—
SUPPRESS statement	1	RPW	X	—
TERMINATE statement	1	RPW	X	—
TRACE statement		EXT	—	—
UNSTRING statement	2	NUC	X	X
USE statement		DBM	—	—
EXCEPTION/ERROR PROCEDURE				

Table 14-2 (Cont.) COBOL Language Features

Features	Implementation Level and Module Code		ANSI-74 X3.23	COBOL-81 V2
PROCEDURE DIVISION				
Global phrase (Continued)				
ON file-name INPUT/OUTPUT/I-O	1	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
ON file-name series	2	SEQ	X	X
	2	REL	X	X
	2	INX	X	X
ON EXTEND	2	SEQ	X	X
LABEL PROCEDURE	2	SEQ	—	—
BEFORE REPORTING	1	RPW	X	—
Global phrase				
USE FOR DEBUGGING statement				
procedure-name	1	DEB	X	—
procedure-name series	1	DEB	X	—
ALL PROCEDURES	1	DEB	X	—
ALL REFERENCES OF identifier	2	DEB	X	—
file-name series	2	DEB	X	—
cd-name series	2	DEB	X	—
WRITE statement				
record-name	1	SEQ	X	X
	1	REL	X	—
	1	INX	X	X
FROM identifier	1	SEQ	X	X
	1	REL	X	X
	1	INX	X	X
BEFORE/AFTER ADVANCING				
integer LINES	1	SEQ	X	X
identifier LINES	2	SEQ	X	X
mnemonic-name	2	SEQ	X	—
PAGE	1	SEQ	X	X
AT END-OF-PAGE	2	SEQ	X	X
INVALID KEY	1	REL	X	X
	1	INX		X
END-WRITE	1	SEQ/REL/INX	—	—
SEGMENTATION				
segment-number (priority-number)	1	SEG	X	X
Fixed Memory Range 0–49	1	SEG	X	X
Non-fixed Memory Range 50–99	1	SEG	X	—
SEGMENT-LIMIT	2	SEG	X	X

Table 14-2 (Cont.) COBOL Language Features

Features	Implementation Level and Module Code		ANSI-74 X3.23	COBOL-81 V2
LIBRARY				
COPY	1	LIB	X	X
text-name	1	LIB	X	X
literal		EXT	—	X
OF/IN LIBRARY	2	LIB	X	—
REPLACING	2	LIB	X	X
May appear anywhere a COBOL word may appear	1	LIB	X	X
Pseudo-text may be replaced	2	LIB	X	—
Identifier may be replaced	2	LIB	—	X
Literal may be replaced	2	LIB	—	X
word	2	LIB	—	X
from Dictionary		LIB	—	—
REFERENCE FORMAT				
Sequence Numbers	1	NUC	X	X
may be omitted		EXT	—	X
Area A	1	NUC	X	X
Division header	1	NUC	X	X
Section header	1	NUC	X	X
Paragraph header	1	NUC	X	X
Data Division entries	1	NUC	X	X
Area B	1	NUC	X	X
Paragraphs	1	NUC	X	X
Data Division entries	1	NUC	X	X
Continuation of Lines				
Nonnumeric Literals	1	NUC	X	X
Words and Numeric Literals	2	NUC	X	X
Comments				
With *	1	NUC	X	X
With /	1	NUC	X	X
With D	1	DEB	X	—
With A–Z	1	EXT	—	—
FIPS INFORMATION				
FIPS Flagging at				
Low		FIP	—	—
Low-Intermediate		FIP	—	—
High-Intermediate		FIP	—	—
High		FIP	—	—

Table 14-2 (Cont.) COBOL Language Features

Features	Implementation Level and Module Code	ANSI-74 X3.23	COBOL-81 V2
Low Level	FIP	—	—
Low-Intermediate	FIP	—	X
High-Intermediate	FIP	—	—
High	FIP	—	—


RLO2
digital 11/23
PDP 11/23 PLUS
RLO2

Chapter 15

DIBOL-83

Digital's DIBOL Language is Concise and Easy to Use.

Digital's business-oriented programming language, DIBOL, was the first high-level commercial data processing language designed specifically to let application programs run in an interactive environment. Programs can do data manipulation, evaluation of arithmetic expressions, subscripting, record redefinition, calls to subroutines, and sequential, indexed, and random access to files. In addition, the interactive online debugging utility simplifies the programmer's job of isolating and correcting program errors.

Because of its high interactivity, DIBOL is a good program development language. Its simple syntax and free-form coding make the language easy to learn while providing for simpler program documentation.

DIBOL can be used in multijob timesharing environments to permit several application programs to run simultaneously. Of course, programs written for timesharing can also run on a single-user system. Another important language feature is the availability of external subroutine libraries. Because subroutines can be held in libraries, programmers can create more compact programs, increasing efficiency and productivity. Such subroutines can be either Digital-supplied or user-developed.

DIBOL has simple, English-like statements that offer:

- A full ASCII character set
- Multilevel data access via file, record, field, and sub-field
- Subscripting
- Array handling
- Record overlays
- Subroutine overlays
- Predefined external DIBOL subroutines
- Internal subroutines
- Program sequence control (chaining) (ISAM)
- Rounding
- File initialization and file labeling
- Branching

DIBOL Is a Structured Language.

A DIBOL program is separated into two major parts: a Data Division and a Procedure Division. The Data Division contains the nonexecutable data specification statements that define the characteristics and identity of the data used by the program. The Procedure Division contains all the program statements that implement the actions or tasks to be performed. PROC and END statements are used to define the program structure. The PROC statement separates the Data Division statements from the Procedure Division statements, and the END statement specifies the logical end of the program.

DIBOL-83 Enriches the Language By Adding New Statements for Block Structure and Loop Control.

DIBOL-83 is the newest version of DIBOL. This standard is the basis for a new expandable compiler that is bundled into every DIBOL product. The DIBOL-83 programming language is provided as part of the CTS-300 commercial operating system, which itself is based on the RT-11 operating system. It is also available as an option on RSX-11M-PLUS and RSTS/E, as well as on VAX/VMS and P/OS, the operating system for the Professional 300 series of personal computers.

The DIBOL-83 compiler supports all the previous DIBOL statements and also the following set of statements, which support structured programming concepts:

BEGIN-END	Allows a group of statements to appear wherever a single statement could appear
DO-UNTIL FOR WHILE	Used for loop control
IF-THEN-ELSE USING	Allows conditional execution of one of a series of statements

The DIBOL-83 compiler optimizes new or old DIBOL programs and reduces their size between two and eight percent. This saves disk space and user memory. Old programs can be recompiled to take advantage of these newly introduced optimizations.

Statement Types Consist of English Language Verbs.

A DIBOL statement has one or more elements. The first element is usually an English verb that characterizes an action to be performed. The other elements of the statement are arguments, which consist of symbolic data names, references to statement labels, and expressions of data values or relationships. Arguments specify the objects of the action performed by the statement.

DIBOL statements fall into seven functional groups: compiler directives, compiler declarations, data specifications, data manipulation, control, intertask commu-

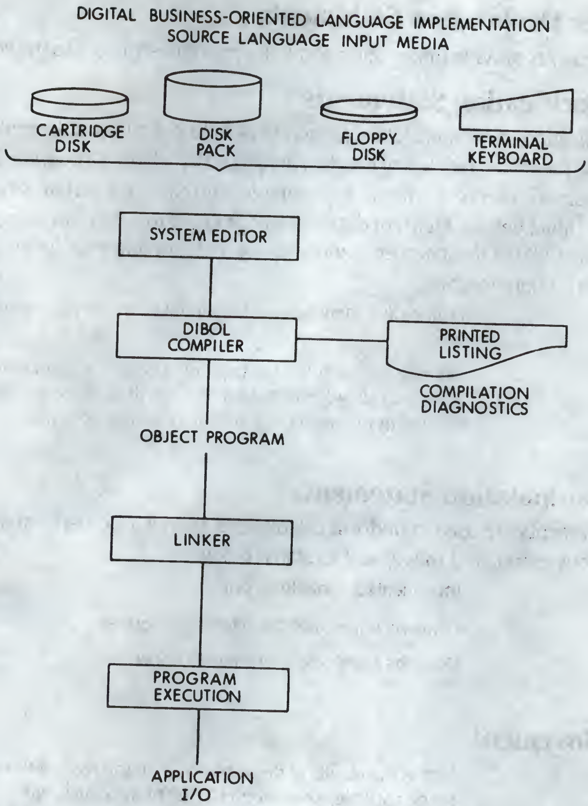


Figure 15-1 DIBOL Implementation

nications, and input/output. They include both arithmetic and logical expressions. The operators in an expression represent various arithmetic and manipulative functions of the DIBOL language. Operators are classified either as unary or binary operators and include most of the usual arithmetic, relational, and boolean operations. In addition, there is a simple mechanism for formatting converted decimal data.

Compiler Directive Statements

As the name suggests, these are instructions to the compiler; they are not executable at runtime and do not affect program operation. Among the compiler directives are statements that identify programs as external subroutines, that separate Data Division statements from Procedure Division statements, that cause the program listing to skip to a new page, that end the program, and that perform other, similar chores.

Compiler Declaration Statements

These statements provide information about the program structure to the compiler.

Data Specification Statements

Data specification statements (also referred to as field definition statements) define and identify the characteristics of the data processed by a DIBOL program. Data can be either numeric or alphanumeric, for example, and can have certain size requirements and initial values. Fields of data that are grouped together are preceded by a RECORD or COMMON statement, and may be redefined at that level. The data specification statements are:

RECORD	Defines and identifies the beginning of one or more grouped fields
COMMON	Defines and identifies the beginning of one or more grouped fields and allows external subroutines directly to use/share a field defined in the main program Data Division section

Data Manipulation Statements

These statements are used to perform calculations as well as to perform data modification, conversion, and movement as stated below:

INCR	Increments a variable by one
LOCASE	Converts uppercase characters to lowercase
UPCASE	Converts lowercase characters to uppercase

Data Movement

=	Moves the results of the expression on the right of the equal sign to the variable specified on the left of the equal sign

The operators in an expression represent various arithmetic and manipulative functions of the DIBOL language. Operators are classified either as unary or binary operators and include most of the usual arithmetic, relational, and boolean operations. In addition, there is a simple mechanism for formatting converted decimal data.

Control Statements

Control statements govern the order of a program's instruction by modifying the normal sequence of statement execution. Some control statements call either internal or external subroutines (CALL, XCALL). Some transfer control to other statements (GOTO). Some execute a statement based on the results of a logical condition (IF). In addition, there are controls for disabling and enabling trapping of runtime errors (OFFERROR, ONERROR), for returning from subroutines (RETURN), for suspending program operation for specified intervals (SLEEP), for terminating execution, and (optionally) chaining to another program (STOP).

Intertask Communications Statements

These statements allow communication between programs. The intertask communicatons statements are SEND and RECV.

Input/Output Statements

Input/output statements control the transmission and reception of data between memory and PDP-11 input/output devices such as disk, lineprinter, and terminal. The input/output statements are:

ACCEPT	Reads a character from a device
CLOSE	Terminates use of an input/output channel and closes the associated file
DELETE	Deletes a record from an ISAM file
DISPLAY	Writes a character string to a device
FORMS	Sends special form control characters used by lineprinters
LPQUE	Requests printing of a file by a spooling program
OPEN	Initializes a file in preparation for I/O operations
READ	Reads a record from a file (direct access)
READS	Reads the next record in sequence from a file
UNLOCK	Releases a file record for access by another program when operating in a timesharing environment
WRITE	Writes a record to a file (direct access)
WRITES	Writes the next record in sequence to a file

Documentation Makes Transporting Your Applications Easy.

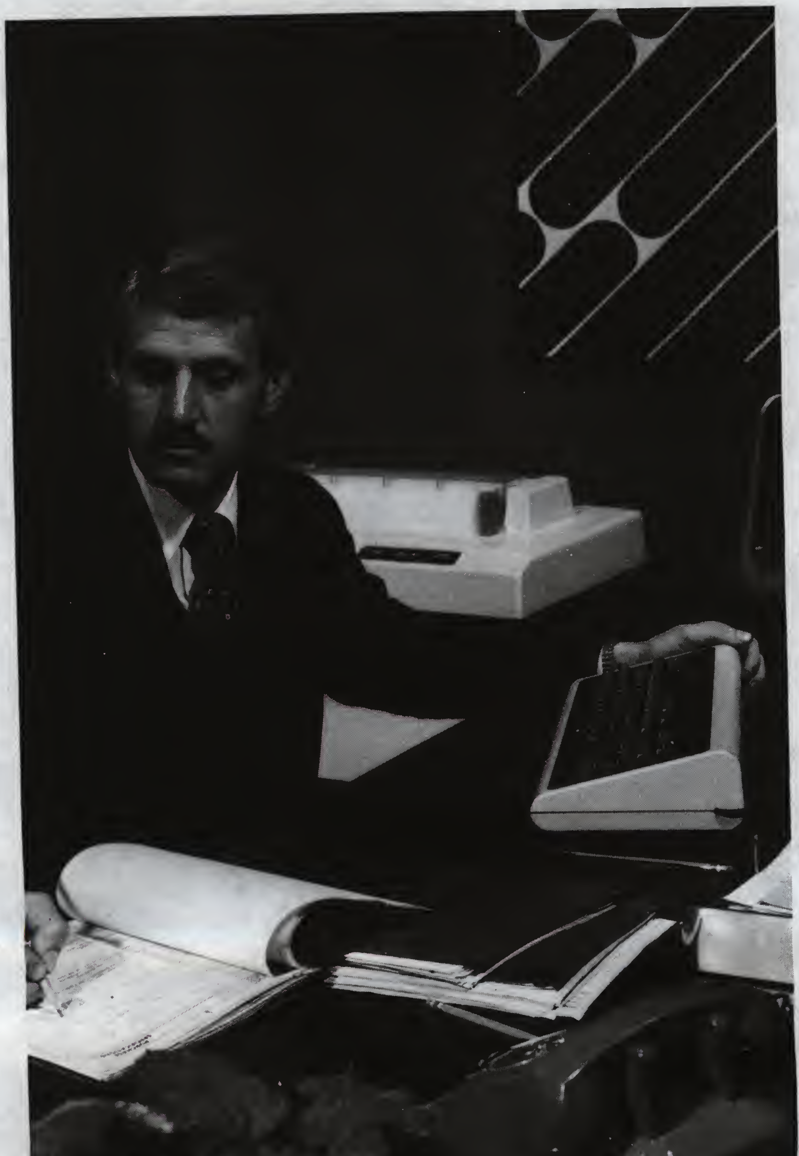
Digital provides documentation for reference, development, and compatibility. These include:

- ***Introduction to DIBOL-83***
  This manual includes an introduction to DIBOL and is intended for all Digital operating systems that support DIBOL-83.
- ***The DIBOL-83 Language Reference Manual***
  This manual contains definitions and formats, along with rules of use and errors for each language statement.
- ***The DIBOL User's Guide***
  This guide describes program development and has been developed for each Digital operating system on which DIBOL runs.

- ***The DIBOL-83 Compatibility Guide***
  This guide was written for users who will be transporting applications across Digital operating systems. It explains the few remaining DIBOL differences and extensions, as well as describing the utilities used when moving programs and data files from system to system.

You Can Debug Your Programs Quickly.

The DIBOL Debugging Technique (DDT) allows you to interact with your DIBOL program while it is executing. Using DDT, you can set predetermined stopping points (called breakpoints) where you wish to temporarily suspend execution of the program. You can examine or alter the contents of variables using their symbolic names, trace through complicated sequences of subroutine nestings, and single step through lines of a DIBOL program. If you miss an error and the program aborts, DIBOL tells you the name of the program that failed and which statement caused the program to fail. These features allow you to locate problems, correct data values, and identify programming errors directly, before re-editing, recompiling, and relinking your program.



Chapter 16
PASCAL/RSX

PASCAL/RSX Gives You Standard PASCAL Features Plus Powerful Enhancements.

PASCAL is a high-level, structured programming language widely used in business, manufacturing, research, and education. PASCAL's English-like commands, completely logical grammar, and block structure help developers produce programs that have clear organization and linear flow. The fact that programs are easily understood and maintained helps to control software maintenance costs.

PDP-11 PASCAL/RSX runs on all RSX-11M or RSX-11M-PLUS based PDP-11 systems that have the Extended Instruction Set (EIS). It includes the features of the Level 0 ISO Specification for Computer Programming Language Pascal (DIS 7185) plus powerful enhancements designed to increase programmer efficiency.

PDP-11 PASCAL/RSX Provides Powerful Extensions to Standard PASCAL.

Some PDP-11 PASCAL/RSX extensions enhance Pascal's modular capabilities and make it easier to develop portions of the same program independently.

These include:

- The MODULE reserved word, which identifies separate modules for independent compilation.
- The %INCLUDE directive, which allows multiple compilation units to include the test of the same program.
- The EXTERNAL command, which allows references to subprograms and data external to the PASCAL program. This increases your ability to develop and compile modules separately.
- The FORWARD command, which lets you declare any subprogram's header and body separately to accommodate those algorithms where separate headers increase clarity and elegance.

Other extensions make PDP-11 PASCAL/RSX easier to use and help increase programmer productivity. These include:

- The OTHERWISE clause in the CASE statement, which provides a succinct way to force execution of statements if the case selector does not match any of the case labels.

- The dollar sign ($) and underscore (_), which can be used in identifiers to enhance program readability.
- Value initialization in the declaration section of the program, which lets you assign initial values to variables, thereby helping to keep executable code size down.
- Predefined functions and procedures, which include OPEN, CLOSE, DATE, UPDATE, FIND, ADDRESS, TIME, and HALT.
- Language elements, which support sequentially organized File Control Services (FCS) files, giving you sequential access to files with variable-length records, and sequential and direct access to files with fixed-length records.
- STATIC, AUTOMATIC, and OVERLAID allocation attributes, which let you specify the type of storage that a variable or compilation unit should occupy.

PDP-11 PASCAL/RSX also contains extensions that enhance mathematical and computing capabilities. These are:

- A REM operator to supply the remainder in division operations.
- Binary, hexadecimal, and octal constants.
- An exponentiation operator.

You Have Convenient Access to the RSX Operating System.

PDP-11 PASCAL/RSX programs can call RSX system services for process-control operations, execution of system directives, and special peripheral access.

PASCAL/RSX also provides a variety of compile-time and task building options, and can support sequential File Control Services (FCS) files with fixed- or variable-length records.

Compile Time Options

PDP-11 PASCAL/RSX options can be specified in the compiler command line. These options include compile-time and runtime checks for array bounds, case selectors, pointers, string bounds, and subrange bounds. These options save valuable programming and debugging time by identifying many common errors.

Compiler options include optional machine code listings with line numbers to aid in debugging. To aid in program migration to other systems, you can call for listings with warning-level messages that identify the use of PASCAL/RSX extensions.

Applications using floating-point arithmetic can take advantage of the *Extended Instruction Set* (EIS), *Floating Point Processor* (FPP), or *Floating Point Instruction Set* (FIS) instructions.

Task Builder Options

The *Task Builder* is used after compilation to produce an executable image file and to provide support for both resident and relocatable object libraries. Task Builder

options create check-pointable tasks, identify the use of floating point hardware, provide online debugging support through the *Online Debugging Technique* (ODT), and allow simultaneous execution of multiple versions of a single task.

Sequential or Direct Record Access—Plus Fixed or Variable-Length Records

PDP-11 PASCAL/RSX supports sequential *File Control Service* (FCS) files that can have fixed-length or variable-length records. Even though FCS files are organized sequentially, PDP-11 PASCAL/RSX provides direct access on all files with fixed-length file organizations.

You select an access mode simply by specifying one parameter in the OPEN procedure. In direct access, the convenient FINK procedure lets you position the file pointer so that the GET or UPDATE acts on the exact file component you want. This easily coded, direct access can help you reduce execution time.

Block Structuring Encourages Efficient Modular Programming.

A PASCAL program consists of two major components: a *HEADING* and a *BLOCK*. The HEADING defines the BLOCK's name and any external files the program will use for input and output. The BLOCK contains two sections of a program, procedure, or function: the *DECLARATION SECTION* and the *EXECUTABLE SECTION*.

Within the DECLARATION SECTION, all data and procedures to be executed must be specified. The EXECUTABLE SECTION contains the statements outlining actions to be performed within the BLOCK. BLOCKS can be nested within the procedure section of other BLOCKS.

The delimiters BEGIN and END are used to specify the beginning and end of the EXECUTABLE SECTION. They provide the framework for logical, yet flexible, programming techniques in conjunction with the following formatting capabilities:

- Free formatting of program text—You can place statements anywhere on a line, divide a statement across more than one line, or place several statements on one line.
- No line numbers—The semicolon (;) is the delimiter that separates successive PASCAL statements. It is also used to terminate the program heading and the items in the declaration section.
- Comments can appear anywhere within a program and are denoted by brace enclosures ({ }) or parentheses and asterisk enclosures ((* *)).

A PDP-11 PASCAL/RSX compilation unit can be a program or a module, with the module consisting solely of a declaration section.

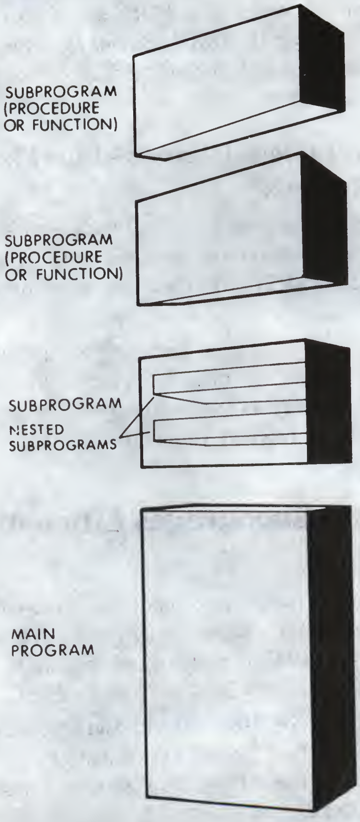


Figure 16-1 Block Structuring

Every Constant, Variable, and Function Designator is Implicitly or Explicitly Associated with a Data Type.

There are four categories of data types: ordinal types, the real type, structured types, and pointer types.

An *ordinal type* consists of an ordered sequence of values that can be represented by a sequence of successive integers; that is, any scalar type whose values are not real numbers.

PDP-11 PASCAL/RSX provides three predefined ordinal types (INTEGER, CHAR, and BOOLEAN) and two user-defined ordinal types (enumerated types and subrange types). These are described below.

Type INTEGER:	Consists of all the integers in the range -32,768 through 32,767 Can be represented in decimal notation Can be written in binary, octal, and hexadecimal notations
Type CHAR:	PDP-11 PASCAL/RSX uses an extended implementation of the ASCII character set Can use the ORD function to convert any ASCII character to its corresponding ordinal value
Type BOOLEAN:	Consists of the values FALSE and TRUE ORD function returns the ordinal value of 0 for FALSE and 1 for TRUE
Enumerated Types:	Consist of a user-specified lists of constants Defined by listing the values in order, separated by commas, within parentheses ORD function can be used on the value of any enumerated type since each value is automatically associated within an ordinal number Example: (Sun, Mon, Tue, Wed, Thu, Fri, Sat) is a valid enumerated type where the ordinal of Fri returns the value 5.
Subrange Types:	Consist of specified subsets of another data type Specified by lo-bound (lower bound) and up-bound (upper bound) Example: the subrange type 6..12 consists of the integers 6,7,8,9,10,11,12.

REAL values can be expressed in either decimal or exponential notation. The Range and Precision of Type REAL are:

Smallest negative value:	-0.29E-38
Largest negative value:	-1.70E38
Smallest positive value:	0.29E-38
Largest positive value:	1.70E38

Precision:	1 part in 2**23 or 7 decimal digits

A *structured type* consists of component variables or constants that collectively define a PASCAL record, array, set, or file. Structured data types can be processed either by aggregate (as a unit) or by individual components. They include:

RECORD type:	A structured list of variables of the same or different data types.
ARRAY type:	A structured group of variables of the same data type that are ordered by means of one or more indexes (i.e., can be a multideminsional array).
SET type:	An unordered grouping of constants (up to 256) of the same ordinal type.
FILE type:	A sequence of logically related components (values) that in storage are arranged in physical order and treated as a unit.

A *pointer type* consists of the storage addresses of dynamic variables and the predeclared value NIL. A dynamic variable is an undeclared variable that is allocated by the system during program execution.

Expressions Evaluate to a Single Value.

An expression is any data item (constant, variable, or function designator), or any group of data items combined by operators, that evaluate to a single value. Expression Operators include:

	Operator	Example	Result
Arithmetic	+	A+B	Sum of A and B
	-	A-B	Subtraction of B from A
	*	A*B	Product of A and B
	**	A**B	A raised to the power of B
	/	A/B	A divided by B
	DIV	A DIV B	Result of A divided by B, truncated toward zero
	REM	A REM B	Remainder of A divided by B
	MOD	A MOD B	Modulus of A with respect to B

Operator		Example	Result
Relational operators	=	A=B	TRUE if A is equal to B
	< >	A< >B	TRUE if A is not equal to B
	>	A>B	TRUE if A is greater than B
	≥	A≥B	TRUE if A is greater than or equal to B
	<	A<B	TRUE is A is less than B
	≤	A≤	TRUE if A is less than or equal to B
Logical operators	AND	A AND B	TRUE if both A and B are TRUE
	OR	A OR B	TRUE if either A or B is TRUE (or if both are TRUE)
	NOT	NOT A	TRUE is A is FALSE (and FALSE if A is TRUE)
String operators	=	A=B	TRUE if strings A and B have equal ASCII values
	< >	A< >B	TRUE if strings A and B have unequal ASCII values
	<	A<B	TRUE if ASCII value of string A is less than that of string B
	≤	A≤B	TRUE if ASCII value of string A is less than or equal to that of string B
	>	A>B	TRUE if ASCII value of string A is greater than that of string B
	≥	A≥B	TRUE if ASCII value of string A is greater than or equal to that of string B
Set operators	+	A+B	Union of sets A and B
	*	A*B	Intersection of sets A and B
	-	A-B	Set of those elements of A that are not also in B

Operator	Example	Result
=	A=B	TRUE if set A is equal to set B
<>	A<>B	TRUE if set A is not equal to set B
≤	A≤B	TRUE if set A is a subset of set B or is equal to set B
≥	A≥	TRUE if set B is a subset of set A or equal to set A
IN	C IN B	TRUE if C is an element of B

Statements Can Appear Anywhere in the Executable Section of a Program Block, Procedure Block, or Function Block.

Simple statements have no component statements. The structured statements contain one or more component statements that can be simple statements or other structured statements. Statements include:

Compound	Structured	Groups other PASCAL statements into a single unit for consecutive execution.
Assignment	Simple	Assigns a value to a variable.
Empty	Simple	Any statement, partial statement, or absence of a statement that causes no action other than program execution to advance to the next statement.
CASE	Structured Conditional	Causes execution of one or more component statements on the basis of the value of an ordinal expression.
IF-THEN	Structured Conditional	Causes execution of a component statement if a relational or logical expression contained in the IF-THEN statement evaluates to TRUE.

IF-THEN-ELSE	Structured Conditional	Causes execution of either of two components statements on the basis of whether a relational or logical expression evaluates to TRUE or FALSE.
FOR	Structured Repetitive	Causes repetitive execution of a component statement on the basis of the value of an internally incremented or decremented variable.
REPEAT	Structured Repetitive	Causes repetitive execution of one or more component statements until a BOOLEAN expression evaluates to TRUE.
WHILE	Structured Repetitive	Causes repetitive execution of a component statement for as long as a BOOLEAN expression evaluates to TRUE.
WITH	Structured	Allows one to reference the fields of a record with an abbreviated notation.
GOTO	Simple	Causes an unconditional transfer of program control to a statement with a label.
Procedure Call	Simple	Invokes a procedure.

Routines Let You Break a Program Down into Component Parts.

There are two kinds of routines in PASCAL: procedures and functions. A procedure is a program unit that performs a certain operation or group of related operations. A function is a program unit that determines or computes a value and then returns this value to the block that called the function.

A PDP-11 PASCAL/RSX program can include user-written routines, predeclared routines, external routines, Object Time System routines, and routines written in MACRO-11. Routines can be included in a main program directly, by declaring them in a PROCEDURE or FUNCTION section, or can be used as separately compiled modules.

PREDECLARED ROUTINES supplied by PDP-11 PASCAL/RSX include:

- ARITHMETIC functions:

ABS(x)	absolute value of x
ARCTAN(x)	arc tangent of x
COS(x)	cosine of x
EXP(x)	exponential of x
LN(x)	natural log of x
SIN(x)	sine of x
SQR(x)	square of x
SQRT(x)	square root of x

- ORDINAL functions:

PRED(x)	returns the value that immediately precedes x in the ordered sequence of values that compose the ordinal data type of which x is a member.
SUCC(x)	returns the value that immediately succeeds x in the ordered sequence of values that compose the ordinal data type of which x is a member.

- BOOLEAN functions:

ODD(x)	tests whether x is odd or even and returns the value TRUE if x is odd, FALSE if x is even.
EOF(x)	tests whether the file pointer is positioned beyond the end-of-file marker in file x, and returns the value TRUE if it is, FALSE if it is not.
EOLN(x)	tests whether the file pointer is positioned beyond the end-of-line marker in text file x, and returns the value TRUE if it is, FALSE if it is not.

- Transfer functions:

CHR(x)	converts integer x in the range 0 through 255 to the character value in the ASCII character set whose ordinal value is x.

ORD(x)	converts ordinal value x to the integer that represents the position of x in the ordered sequence of values that compose the data type of which x is a member.
ROUND(r)	converts the REAL value r to an INTEGER value by rounding any fractional part of r.
TRUNC(r)	converts REAL value r to an INTEGER value by truncating any fractional part of r.

- Transfer procedures:

PACK	converts an unpacked array into a packed array.
UNPACK	converts a packed array into an unpacked array.

- Allocation routines:

ADDRESS	returns the address of either a static variable or a dynamic variable.
NEW	allocates memory for a dynamic variable.
DISPOSE	deallocates memory in heap storage for a dynamic variable created by the NEW procedure.

- Miscellaneous routines:

DATE AND TIME	assigns the current data and time, respectively, to a variable of type PACKED ARRAY [1..11] OF CHAR.
HALT	causes program execution to stop.

PASCAL/RSX Supports Both Sequential and Direct Access.

A file in PDP-11 PASCAL/RSX is a sequence of logically related components (sometimes called records) that in storage are arranged in physical order and treated as a unit. PASCAL/RSX files are called sequential files. The components that make up any one file must all be of the same data type.

PASCAL/RSX supports two file access methods: sequential and direct. Under sequential access, the components of a file are processed in the sequence in which they are physically ordered. Under direct access, the components of a file are processed in any order, and are selected for processing individually on the basis of their position relative to the physical beginning of a file. File components can be any data type, but all the components in any one file must be the same data type.

PASCAL/RSX supports two kinds of file components: fixed-length and variable length. Fixed-length components are file components that are of a specified size. Variable-length components may be of any size up to a specified maximum.

PASCAL/RSX Provides Predeclared Routines for Performing I/O.

The predeclared routines for performing I/O operations are:

GENERAL PROCEDURES:

OPEN	Opens a file with specified characteristics.
CLOSE	Closes a file.

SEQUENTIAL ACCESS INPUT PROCEDURES:

GET	Reads a file component into the file buffer variable.
READ	Reads a file component into a specified variable.
RESET	Prepares a file for input.

SEQUENTIAL ACCESS OUTPUT PROCEDURES:

PUT	Writes the file buffer variable into the specified file.
REWRITE	Truncates a file to length zero and prepares it for receiving output.
WRITE	Writes specified values into a file.

MISCELLANEOUS ROUTINE:

EOF	Indicates the end of an input file.

TEXT MANIPULATION PROCEDURES:

EOLN	Indicates the end of an input file.
PAGE	Advances output to the next page of text file.

READLN	Reads a line from a text file.
WRITE	Allows one to specify field width to format the values being written in a text file.
WRITELN	Writes a line into a text file.

DIRECT ACCESS PROCEDURES:

FIND	Performs direct access to a file for input operations.
UPDATE	Performs direct access to a file for output operations.

Attributes Let You Control Program Elements.

Attributes allow additional control over the properties of variables, routines, and compilation units. The following table lists the attributes and indicates the program elements with which each attribute can be associated.

Table 16-1 Summary of Attribute Use

Class ding	**Attribute**	**Variable**	**Procedure of Function**	**Program or Module Head-**
	GLOBAL	Yes	Yes	No
Visibility	EXTERNAL	Yes	Yes	No
	LOCAL	Yes	Yes	No
	STATIC	Yes	No	No
Allocation	AUTOMATIC	Yes	No	No
	OVERLAID	No	No	Yes

```
PROGRAM Calculator (INPUT, OUTPUT);

  VAR Subtotal, Operand : REAL;
      Equation : BOOLEAN;
      Operator: CHAR;
      Answer : CHAR;

PROCEDURE Instructions;
  BEGIN
    WRITELN ('This program adds, subtacts, multiplies, and');
    WRITELN ('divides real numbers. Enter a number in response');
    WRITELN ('to the Operand: prompt and enter an operator --');
    WRITELN ('+, -, *, /, or = in response to the Operator:');
    WRITELN ('prompt. The program keeps a running subtotal');
    WRITELN ('until you enter an equal sign (=) in response');
    WRITELN ('to the Operator: prompt. You can then exit from');
    WRITELN ('the program or begin a new set of calculations.');
  END; (* End of Procedure Instructions *)

BEGIN
WRITE ('Do you need instructions? Type Y or N. ');
READLN (Answer);
IF Answer='Y' THEN Instructions;
REPEAT
  Equation := FALSE;
  Subtotal := 0;
  WRITE : ('Operand: ');
  READLN (Subtotal);

  WHILE (NOT Equation) DO
    BEGIN
      WRITE ('Operator: ');
      READLN (Operator);
      IF (Operator = '=') THEN
        BEGIN
          Equation := TRUE;
          WRITELN ('The answer is ',Subtotal);
        END (* End of If clause *)
      ELSE
        BEGIN
          WRITE ('Operand: ');
          READLN (Operand);
          CASE Operator OF
                '+' : Subtotal := Subtotal + Operand;
                '-' : Subtotal := Subtotal - Operand;
                '*' : Subtotal := Subtotal * Operand;
                '/' : Subtotal := Subtotal / Operand;
          END; (* End of CASE statement *)
          WRITELN ('The subtotal is ', Subtotal);
        END; (* End of ELSE clause *)
    END; (* End of WHILE statement *)

  WRITE ('Any more calculations? Type Y or N. ');
  READLN (Answer);
UNTIL Answer = 'N';
END.
```

Figure 16-2 This sample shows the structure of a PDP-11 PASCAL/RSX program. PDP-11 PASCAL/RSX includes the features of the Level 0 ISO Specification for Computer Programming Language PASCAL (Draft Proposal 7185), plus many powerful extensions to the PASCAL language.

Chapter 17

File Management Utilities

PDP-11 operating systems provide a number of utilities and programs that are designed to make file management easy, both in the structuring and in the accessing of files. While the descriptions that follow do not exhaust the list of Digital's file management programs or utilities, they do suggest the breadth of products available.

File Control Services Provide a User Interface to the File System.

RSX-11 File Control Services (FCS) enable you to perform record-oriented and block-oriented I/O operations, and to perform additional functions required for file control, such as open, close, wait, and delete operations. To invoke FCS functions, the user issues macro calls to specify desired file control operations. The FCS macros are then called at assembly time to generate code for specified functions and operations. Figure 17-1 illustrates the file access operation.

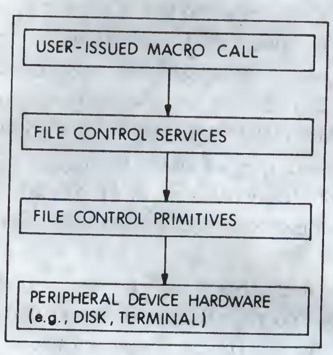


Figure 17-1 File Access Operation

FCS is a set of routines linked with the user program at task-build time from a resident system library or a system object module library. These routines, consisting of pure, position-independent code, provide a user interface to the file system, enabling the user to read and write files on file-structured devices and to process files in terms of logical records.

With FCS, the user can write a collection of data (consisting of distinct logical records) to a file in a way that enables you to retrieve the data at will. Data can be gotten from the file without having to know the exact form in which it was written to the file. FCS thus provides a sense of transparency to the user so that records can be read or written in logical units that are consistent with an application's requirement.

File Access Method

Under FCS, RSX-11 supports both sequential and direct access to files. The sequential access method is device-independent, that is, it can be used for both record-oriented and file-structured devices (for example, card reader and disk, respectively). The direct access method can be used only for file-structured devices.

Data Formats for File-Structured Devices

Data are transferred between peripheral devices and memory in blocks. A data file consists of virtual blocks, each of which may contain one or more logical records. Records in a virtual block can be either fixed or variable in length.

Virtual blocks and logical records within a file are numbered sequentially, starting with *1*. A virtual block number is a file-relative value, while a physical block number is a volume-relative value. For example, the first virtual block in a file is always virtual block number 1, but at the same time it could also be physical block number 156.

Block I/O Operations

The READ and WRITE macro calls allow the user to read and write virtual blocks of data from and to a file without regard to logical records in a file. Block I/O operations provide a very efficient means of processing file data, since such operations do not involve the blocking and deblocking of records within the file. Also, in block I/O operations, the user can read or write files asynchronously; control can be returned to the user program before the request I/O operation is completed.

When block I/O is used, the number of the virtual block to be processed is specified as a parameter in the appropriate READ and WRITE macro call. The virtual block so specified is processed directly in a buffer reserved by the program in its own memory space.

As implied above, the user is responsible for synchronizing all block I/O operations. Such asynchronous operations can be coordinated through an event flag specified in the READ and WRITE call. The event flag is used by the system to signal the completion of the I/O transfer, enabling the user to coordinate those block I/O operations that depend on each other.

Record I/O Operations

The GET and PUT macro calls are provided for processing record-oriented files. GET and PUT operations perform the necessary blocking and deblocking of the records within the virtual blocks of the file, allowing the user to read or write individual records.

In preparing for record I/O operations, the user program must specify the format of the records. For example, it must specify whether the records are fixed or variable in length, or whether records that are to be output to a carriage-control device are to contain carriage-control information, which can be either at the beginning of the record or embedded within the record.

For sequential access files, I/O operations can be performed for both fixed- and variable-length records. For direct access files, I/O operations can be performed only for fixed-length records.

In contrast to block I/O operations, all record I/O operations are synchronous; control is returned to the user program only after the requested I/O operation is performed.

Because GET and PUT operations process logical records within a virtual block, only a limited number of GET or PUT operations result in an actual I/O transfer, that is, when the end of a data block is encountered. Therefore, all GET and PUT I/O requests will not necessarily involve a physical transfer of data.

The File Storage Region

The File Storage Region (FSR) is an area allocated in the user program as the working storage area for record I/O operations. The FSR consists of two program sections that are always contiguous to each other. The first program section of the FSR contains the block buffers and the block buffer headers for record I/O processing. The user determines the size of the area at assembly time. The number of block buffers and associated headers is based on the number of files that the user intends to open simultaneously for record I/O operations.

The second program section of the FSR contains impure data that are used and maintained by FCS in performing record I/O operations. Portions of this area are initialized at task-build time, and other portions are maintained by FCS. This program section is intentionally isolated from the user to preserve its integrity.

Blocking and deblocking of records during input is accomplished in the FSR block buffer during output. Note also the FCS serves as the user interface to the FSR block buffer pool. All record I/O operations initiated through GET and PUT calls are totally synchronized by FCS.

Data Transfer Modes

When record I/O is used, a program can gain access to a record in either of two ways after the virtual block has been transferred into the FSR from a file:

- Move mode—Individual records are moved from the FSR buffer. Move mode simulates the reading of a record directly into a user record buffer, thereby making the blocking and deblocking of records transparent to the user.
- Locate mode—The user program accesses records directly in the FSR block buffer. Program overhead is reduced in locate mode, since records can be processed directly within the FSR block buffer.

Shared Access to Files

FCS permits shared access to files according to established conventions. Two macro calls, among several available in FCS for opening files, can be issued to invoke these functions. The OPNS macro call is used specifically to open a file for shared access. The OPEN call, on the other hand, invokes generalized open functions that have shared access implications only in relation to other I/O requests then issued.

OPNS allows several active read-access requests and one write-access request for the same file. OPEN allows multiple read-access requests for the same file, but does not permit concurrent write access. Note that shared access during reading does not necessarily imply the presence of read requests from several separate tasks. The same task can open the same file using different logical unit numbers.

Spooling Operations

FCS provides facilities at both the macro and subroutine level to queue files for subsequent printing. A task issues the PRINT macro call to queue a file for printing on the system lineprinter.

FCS Macros and Macro Use

FCS includes four basic kinds of macros that simplify the user's interface to the system's file control primitives. The four kinds are:

- Initialization macros
- File-process macros
- Command-line processing macros
- The CALL macro

The initialization and file-processing macros are used to establish the database description and the necessary temporary storage areas needed to perform I/O operations. The command line processing macros are used to process dynamically I/O commands entered from a terminal. The CALL macro is used to invoke file control routines.

The initialization and file-processing macros set up the following structures to define the database:

- A file data block (FDB) that contains execution-time information necessary for file processing. It defines the basic characteristics of a file, that is, record type, record size, access privileges, and so forth.
- A data set descriptor that is accessed by FCS to obtain the file name, type, version number, and location necessary to open a specified file. The data set descriptor is used when a program accesses a given set of known or predefined files.
- A default file name block that is accessed by FCS to obtain default file information required to open a file. This is accessed when complete file information is not specified in the data set descriptor. It is used by programs written to access a general set of files.

There are two types of initialization macros: assembly time macros and runtime macros. Data supplied during assembly of the source program establish the initial values in the FDB. Data supplied at runtime can either initialize additional portions of the FDB or change values established at assembly time. Furthermore, the data supplied through the file-processing macros can either initialize portions of the FDB or change previously initialized values. The user not only has a broad range of control over defining the database characteristics, but also has control over when the definitions are made.

File processing macros also determine the way in which files are processed. These macro calls are invoked and expanded at assembly time. The resulting code is then executed at runtime to perform the following operations:

OPEN	Opens and prepares a file for processing
OPNS	Opens and prepares a file for processing; allows shared access to the file (depending on the mode of access)
OPNT	Creates and opens a temporary file for processing
OFID	Opens an existing file using the file identification provided in the filename block
GET	Reads logical records from a file
GETR	Reads fixed-length records from a file in random access mode
GETS	Reads records from a file in sequential access mode
PUT	Writes logical records to a file
PUTR	Writes fixed-length records to a file in random mode
PUTS	Writes records to a file in sequential mode
READ	Reads virtual blocks from a file
WRITE	Writes virtual blocks to a file
DELETE	Removes a named file from the associated volume directory and deallocates the space occupied by the file
WAIT	Suspends program execution until a requested block I/O is performed
PRINT	Queues a file for printing on a special terminal or lineprinter

In summary, the file-processing macros allow the user to specify random access or sequential access to files, and perform block-oriented or record-oriented file processing. In addition, the PRINT macro allows the user to spool files to a lineprinter or terminal device.

The command-line processing macros allow the user to access special routines available in the system object library. The Get Command Line (GCML) routine accomplishes all the logical functions associated with the entry of a command line from a terminal, an indirect command file, or an on-line storage medium. The

Table 17-1 Selecting the Sorting Process and Devices That Best Suit the Processing Environment

Sorting Technique	Input File	Output File	Work File
SORTR (Record Sort)	Disk Magtape* Paper Tape Cards Console	Disk Magtape* Paper Tape Printer Console	Disk (3-8 files)
SORTT (Tag Sort)	Disk	Disk Magtape* Printer Console Paper Tape	Disk (3-8 files)
SORTA (Address routing Sort)	Disk	Disk	Disk (3-8 files)
SORTI (Index Sort)	Disk	Disk	Disk (3-8 files)

* Provided records are at least 18 bytes long. Magtape must be in ANSI format.

Command String Interpreter (CSI) routine takes command lines from the GCML input buffer and parses them into appropriate data set descriptors required by FCS for opening files.

The CALL macro allows the user to access a special set of file control routines. These routines allow a MACRO program to perform, among other operations, the following: find, insert, or delete a directory entry, rename a file, extend a file, mark a temporary file for deletion, and delete a file,.

SORT Runs on Operating Systems With RMS.

The SORT utility program allows you to reorder data from any input file into a new file in either ascending or descending sequence based on control or key fields within the input data records themselves. SORT runs under any operating system that includes RMS (Record Management Services).

If you do not wish to sort the actual data, SORT can still be used to extract key information, sort that information, and store the sorted information in a permanent file. Later that file can be used to access the data in the order of the key information on the sorted file. The contents of the sorted file may be entire records, key fields, or record indexes relative to the position of each record within the file (the first record on the database is record 1, the second, 2, and so on). SORT provides four sorting techniques which are outlined later in this chapter.

The SORT utility program can be controlled by a command string and an optional specification file. There is a simple format for each. If your SORT application does not require that records be restructured or that only a subset of the input file be sorted, then only a command string is needed to control SORT.

Data Files

SORT can accept a file from any one of the peripheral devices available in a system configuration: disk units, magtape units, or terminals.

A record is usually divided into several logical areas called data fields. The data in each field may or may not be relevant to SORT. SORT uses record identifiers to distinguish the various types of records in a file, while it uses the key fields in each record to reorder an input file. The key fields may be any one of a number of different data types, including character, zoned decimal, two's-complement binary, and two or four word floating point. Any other data field in a record may be retained in the output file or ignored.

Command String and Specification File

The user can direct the SORT program by entering a command string, which serves three functions:

- References devices in the system for each file in the current sort.
- Specifies switches that define file parameters used in the sorting process.
- References a specification file or specifies other switches to control the sort.

Several command string switches define the sorting process parameters. One switch describes record formats and the maximum record size. Another delimits the internal work files. Others provide detailed file information to RMS.

Normally, the sort must be directed with a specification file, but two additional switches may be used instead of a specification file. The first specifies the sorting process option; the second identifies the key fields. The use of these switches is limited to sorting an input file of uniform format:

- The key fields must reside in the same location in every record of the input file.
- The file must contain only the records to be included in the sort. Figure 17-2 illustrates a general sort that would require only a command string and switches.

Figure 17-2 Sort Using Command String and Switches

The specification file is the supplement to the command string, which provides the basis for controlling and directing the sorting process.

The specification file provides a variety of controlling features. They are listed below:

1. Record Selection

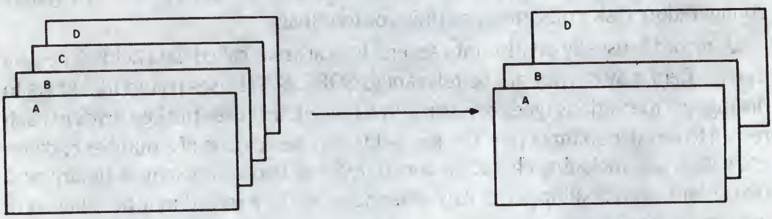


Figure 17-3 Record Selection

You can include or omit any records from the sorting process. The output file will contain only the specified records.

2. Alternate Collating Sequence

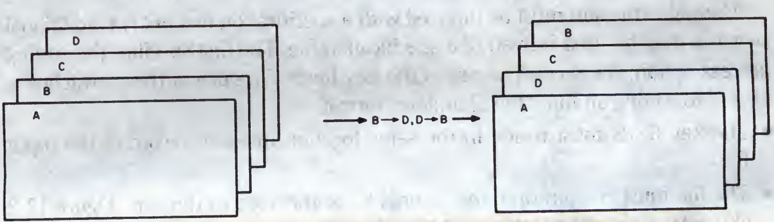


Figure 17-4 Alternate Collating Sequence

If necessary, you can specify an alternate collating sequence. The normal sequence is that implied in ASCII code. One alternate choice is EBCDIC values. The other is an individual alternate collating sequence (ALTSEQ). An ALTSEQ can be used to change the ASCII values of the normal sequence. It applies to all the alphanumeric key data in the records, but only during the actual sorting process. The output record remains unchanged.

3. Forced Keys

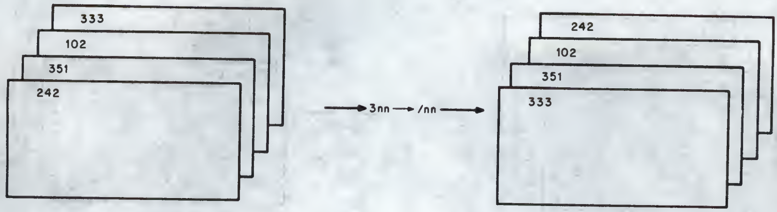


Figure 17-5 Forced Key

An ALTSEQ applies to all positions of the key. Forced keys allow the user to specify an alternate sequence for particular positions within the key. An alternate can be specified by substituting a lower-valued character, such as the slash (/) in the example above. Since the slash comes before 0, the 300-series records in the example are brought to the front of the file. Notice that the records so treated are in sequence and in front of the rest of the sorted file. The net effect is that of two sorted files, one behind the other.

4. Input Format Variation

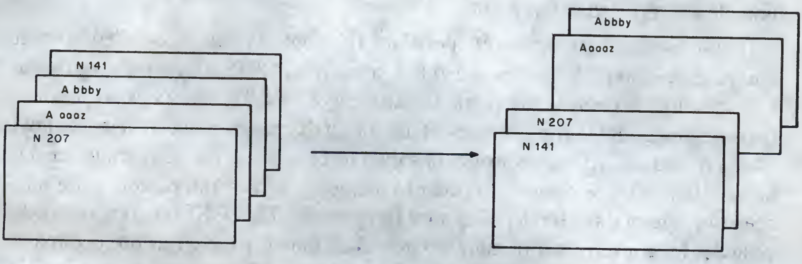


Figure 17-6 Input Format Variation

If the input file contains records with several different formats, the user can identify those records by type so that they may be properly handled. Note that only one type may be selected and sorted per run.

In the example above, A and N are record identifiers.

5. Output Format Variation

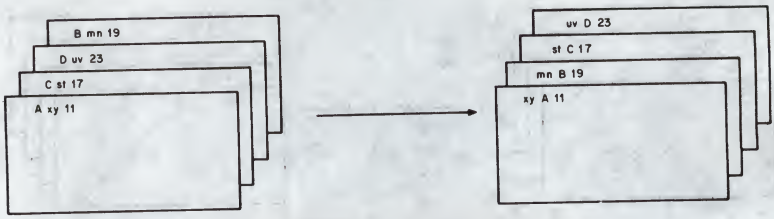


Figure 17-7 Output Format Variation

You can change the format of the data file during the sort, but you cannot change the contents of any given data item.

SORT Operation

The SORT program consists of two basic parts: a control program and a subroutine package called SORTS. The control program directs the overall processing, while SORTS serves as a collection of subroutines available to the control program during its processing. The subroutine package can be invoked from a user-written program. This is supported in most PDP-11 programming languages.

There are three phases of operation in the SORT control program. In the first phase, SORT reads the command string, decodes it, and stores the switch values and the specification file, if present. Any errors in the command string or specification file are reported at this point.

Phase two begins the presort operation. The control program is called to open and read the input file and establish the keys. The SORTS subroutine begins the initial sorting process. At this point, the amount of available internal storage space becomes important to the efficiency of the sort. If that space is not sufficient to hold all the records, SORT builds strings of sorted records and transfers them to scratch files on bulk storage devices. In order to merge these files and complete the sort, space for at least three scratch files must be available. The SORT program normally provides for a maximum of eight scratch files. Either a switch in the command string or the amount of available internal work space can reduce the number of scratch files used.

The final merge phase rebuilds the intermediate scratch files into a merged file. Another subroutine reads the records in the proper sequence. The records are then written into the output file. If there are no scratch files to merge because main memory was sufficient to hold all the records, the sorted records are written directly into the output file. After the last record is written, the control program cleans up the scratch files and returns to the first phase. SORT is then ready to accept another job.

SORT PROCESSING OPTIONS

Table 17-2 Sorting Process Options

Type of SORT	Type of File	Record Size and Format	Speed	Device
SORTR (Record Sort)	Input and Output	Any	Slowest	Any
SORTT (Tag Sort)	Input	Any	Slow for large file	Disk
	Output	Any		Any
SORTA (Address Routing SORT)	Input	Any	Fastest	Disk
	Output	Fixed, six bytes		Any
SORTI (Index Sort)	Input	Any	Fast	Disk
	Output	Fixed, 6-byte pointer + original key		Any

Record Sort (SORTR)

The Record Sort (SORTR) outputs all specified record data in a sorted sequence. Each record is kept intact throughout the entire sorting process. Since it moves the whole record, SORTR is relatively slow and may require considerable main memory or external storage work space for large files.

Tag Sort (SORTT)

The Tag Sort (SORTT) produces the same kind of output file as SORTR, but it handles only record pointers and key fields. Since SORTT moves a smaller amount of data than SORTR, SORTT usually performs a faster sort than SORTR. The input file must be randomly reaccessed to create the entire output file, which may be a lengthy process for large files.

Address Routing Sort (SORTA)

SORTA produces address routing files, which consist of relative record pointers, beginning at 1, in binary words. These files can be used as a special index file to access randomly the data in the original file. It is possible to maintain only one data file while maintaining several different index files as needed. Like SORTT, SORTA uses the minimum amount of data necessary in the sorting process. Once the input phase is completed, the input file is not read again. The output data are in a restricted mode. This means that SORTA is the fastest sorting method in the SORT package.

Index Sort (SORTI)

SORTI produces an index file consisting of relative record pointers, as in SORTA, and index keys. This makes it slightly slower than SORTA. During processing, SORTI handles only the relative record pointers and two forms of the key fields. One form is used for sorting and the other is left as it was in the original data.

Other Utilities Help Make the Operations You Need Easier and Quicker.

Running across most systems is a group of file management utilities that help make the various operations you need easier and quicker. The major features of these utilities are listed below.

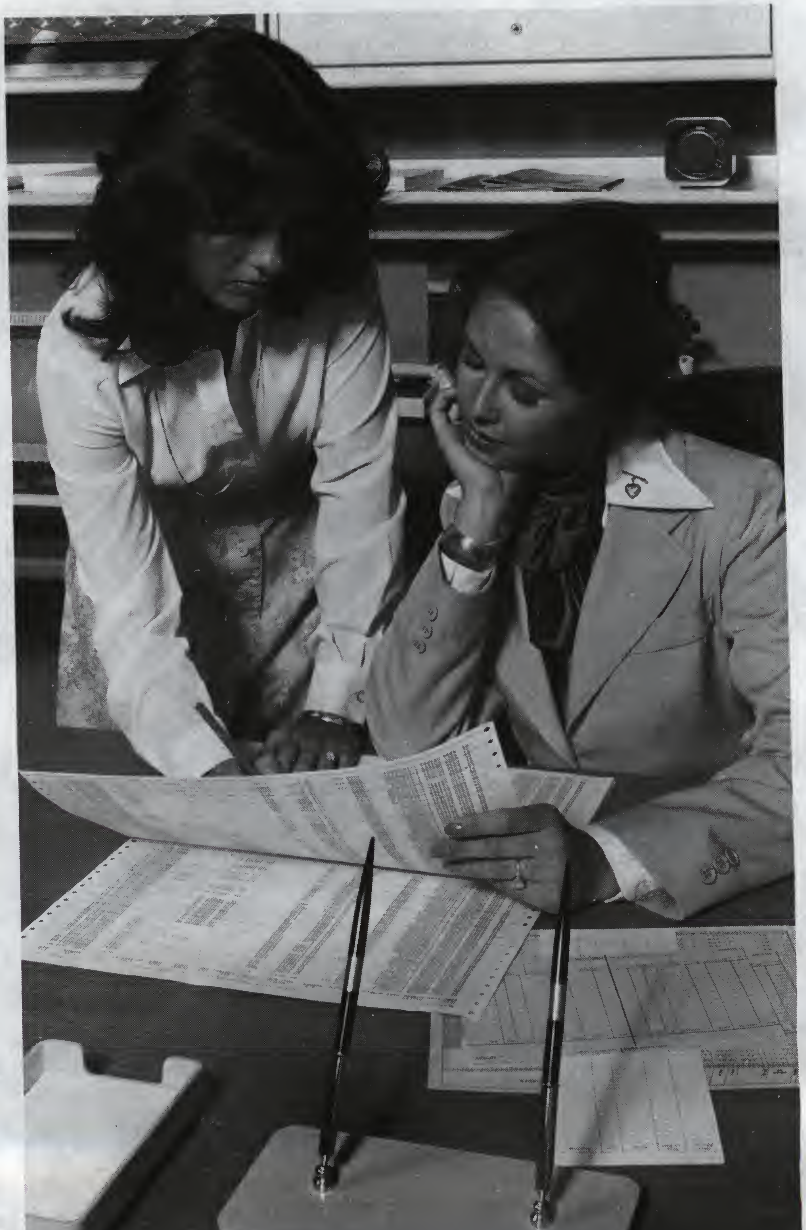
PIP	The Peripheral Interchange Program (PIP) is a general purpose file utility package for general users programmers and system managers. PIP normally handles all files with the operating system's standard data formats. In general, the program transfers data files from any device in the system to any other device in the system. PIP can also delete or rename any existing file. Some operating systems include special file management operations in the PIP utility, such as directory listings, device initialization and formatting, and account creation.
FILEX	A File Exchange program, this special purpose file transfer utility is similar in operation to PIP. It provides the ability to copy files stored in one kind of format to another format. This enables a user to create data on one system in a special format and then transfer the data to a device in a format that another system can read. (This program is called FLX on RSX-11 systems).
DUMP	DUMP displays all or selected portions of a file on a terminal or lineprinter. In general, DUMP enables the user to inspect the file in any of three modes: ASCII, byte, or octal. In ASCII mode, the content of each byte is printed as an ASCII character. In byte mode, the content of each byte is printed as an octal value. In octal mode, the content of each word is printed as an octal value. (This is called DMP on RSX-11 systems).
VERIFY	In general, a VERIFY program checks the readability and validity of data on a file-structured device. (This is called VFY on RSX-11 systems).
DUP	This is a device maintenance utility program. DUP creates files on file-structured RT-11 devices. It can also extend files on certain file-structured devices such as disks, and it can compress, image copy, initialize, or boot RT-11 file structured devices. DUP does not operate on nonfile-structured devices such as lineprinters or terminals.
DSC	DSC enables the user to backup and restore disk volumes to magnetic tape or to other disks and to combine unused blocks on disks to create contiguous blocks. DSC comes both as a standalone and as an online program.

CMP

CMP is a utility that compares, line by line, two ASCII files. Its output can be either a new file with all the differences encountered, a listing of one file with change bars marking the differences, or an output suitable for input to the SLP utility.

BRU

BRU backs up an RP06 disk to TU45 tape in less than an hour, which is approximately a 4-to-1 improvement over previous DSC programs. BRU also supports incremental backups (such as backing up only the files that have been modified since the previous backup), which greatly reduces the amount of time required for proper disk backup.



Chapter 18

Record Management Services (RMS)

RMS Organizes and Accesses Records Within Files.

Record Management Services, a set of general purpose file-handling capabilities, combines with a host operating system to provide efficient and flexible data storage and modification. When writing programs, you can select processing methods suitable to your application from among several RMS file structuring and accessing techniques.

Not only does RMS handle such functions as file organization and access methods, but it also manages the other file attributes (for example, storage medium and record format) and the runtime environment. By accomplishing most of its work transparently, RMS relieves programmers of many of the complexities associated with file and record manipulation.

RMS on the PDP-11 family is called RMS-11. It's included as part of RSX-11M-PLUS, RSX11-M, and RSTS/E, as well as VAX/VMS and P/OS, the operating system of the Professional 300 series of personal computers. It also provides a common data format for transport among these systems. Through RMS, programmers can maintain data files created by BASIC-PLUS-2, COBOL-81, MACRO-11, and DIBOL programming languages. Depending on the language in which programs are written, various RMS capabilities are available. When writing programs, programmers can select processing methods among the RMS file organizations and accessing techniques.

Files Collect Related Information.

A *file* is a collection of related information whose requirements are established by the nature of application programs needing the information. A company might maintain personnel information (employee names, addresses, job titles) in one file, for example, and product information (part numbers, prices, specifications) in a second, separate, file. Within each of these files, the information is divided into *records*. In the personnel file, it would be logical for all the information on a single employee to constitute a single record and for the number of records in the file to equal the number of employees. Similarly, each record in the product information file would represent a description of a single product. The number of records in the file reflects the requirements of a particular application, in this case, a central registry of products sold by a company.

Each record in the personnel and product files would be subdivided into discrete pieces of information known as *data fields*, whose number, location within the record, and logical interpretation are defined by the programmer. Program applications then interpret, for instance, a particular data field in records of the personnel file as the name of an employee. They would interpret another data field in records of the product file as a part number. Figure 18-1 illustrates records that might occur in a personnel file and in a product file.

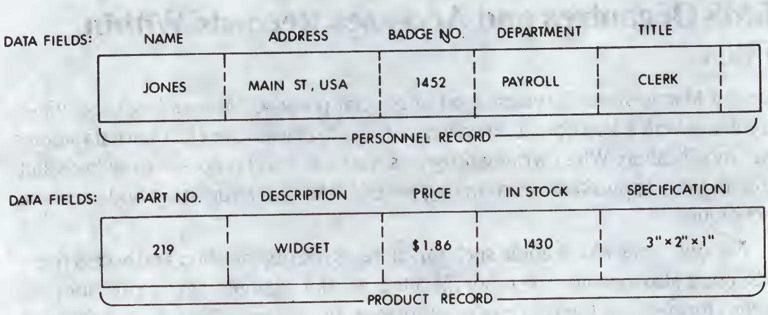


Figure 18-1 Personnel and Product Records

Thus, the relationships among data fields and records are known and are embedded in the logic of the programs. RMS does not require an awareness of such logical relationships; rather, RMS processes records as single units of data. *Programs either build records and pass them to RMS for storage in a file or issue requests for records while RMS performs the necessary operations to retrieve the records from a file.*

The purpose of RMS, then, is to ensure that every record written into a file can subsequently be retrieved and passed to a requesting program as a single logical unit of data. The structure, or *organization*, of a file establishes the manner in which RMS stores and retrieves records. The way a program requests the storage or retrieval of records is known as the *access mode*. Legal access modes depend on the organization of a file.

Three File Organizations Govern the Relationships of Records.

When creating a file, you have a choice of three file organizations:

- Sequential
- Relative
- Indexed

RMS also supports three record access modes (techniques for storing and retrieving file records): sequential, random, and Record's File Address (RFA).

Among the attributes specified when creating an RMS file are:

- Storage medium
- Filename and protection specifications
- Record format and size
- File allocation information

After RMS creates a file according to the specified attributes, application programs can use RMS access modes to store, retrieve, and modify data. These program operations take place on the logical records in a file or in the blocks the file comprises.

Sequential File Organization

In sequential file organization (see Figure 18-2), records appear in a physical sequence that is always identical to the order in which the records were originally written to the file by an application program.

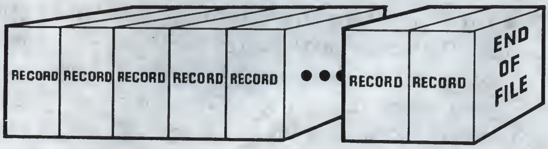


Figure 18-2 Sequential File Organization

Relative File Organization

When relative organization is selected, RMS structures a file as a series of fixed-size record cells. Cell size is based on the size specified as the maximum permitted length for a record in the file. RMS considers these cells as successively numbered from 1 (the first) to n (the last), and the cell's number represents its location *relative* to the beginning of the file.

Each cell in a relative file can contain a single record. There is no requirement, however, that every cell contain a record. Empty cells can be interspersed among cells containing records.

Since cell numbers in a relative file are unique, they can be used to identify both a cell and the record (if any) occupying that cell. Thus, record number 1 occupies the first cell in the file, record number 17 occupies the seventeenth cell, and so forth. When a cell number is used to identify a record, it is also known as a *relative record number.* Figure 18-3 depicts the structure of a relatively organized file.

Indexed File Organization

Unlike the physical ordering of records in a sequential file or the relative positioning of records in a relative file, the location of records in indexed file organization is

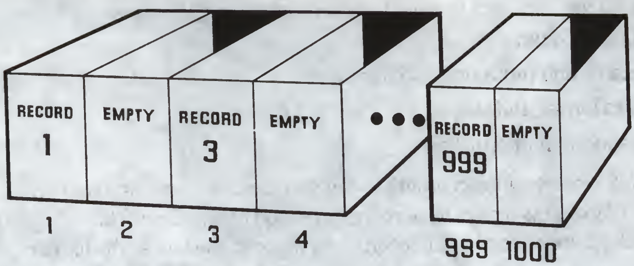


Figure 18-3 Relative File Organization

transparent to the program. RMS completely controls the placement of records in an indexed file. The presence of *keys* in the records of the file governs this placement.

The key, chosen by the programmer, is a data type present in every record of a particular indexed file. The location and length of this data type are attributes of the file, and therefore are identical for all records in the given file. Legal key data types are: string (1-255 bytes), integer (2 and 4 bytes), unsigned binary (2 and 4 bytes), and packed decimal (1-16 bytes). Selecting a data type indicates to RMS that the content (that is, key value) of that key in any particular record written to the file can be used by a program to identify that record for subsequent retrieval. Since the key is the arbitrary choice of the programmer, it can, of course, be equal to a field. Therefore, in the inventory file, the part number field could be a key; in the personnel file, the last name field could be a key.

At least one key, the *primary key*, must be defined for every indexed file. Optionally, additional *alternate keys* can be defined. Each alternate key represents an additional character string in records of the file. The key value in any one of these additional strings can also be used to identify the record for retrieval.

As programs write records into an indexed file, RMS locates the values contained in the primary and alternate keys. From the values in keys within records, RMS builds a tree-structured table known as an index, consisting of a series of entries, each of which contains a key value copied from a record that a program wrote into the file. With each key value is a pointer to the location in the file of the record from which the value was copied. RMS builds and maintains separate indexes for the primary and alternate keys defined for the file. Each index is stored in the file. Figure 18-4 shows the general structure of an indexed file that has been defined with only a single key. Figure 18-5 depicts an indexed file defined with two keys: a primary key and one alternate key.

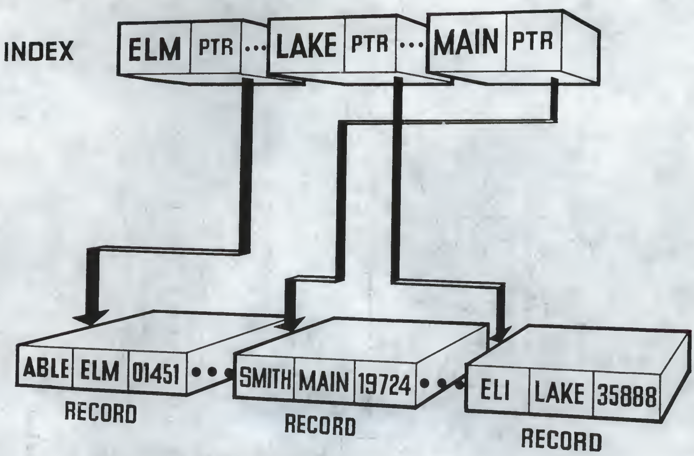


Figure 18-4 Single Key Indexed File Organization

RMS Provides Three Record-Access Modes.

The various methods of retrieving and storing records in a file are called access modes. A different access mode can be used to process records within the file each time it is opened. Additionally, a program can change access mode during the processing of a file, by a procedure known as dynamic access.

RMS provides three record-access modes:

- Sequential
- Random
- Record's file address (RFA)

For logical reasons, RMS permits only certain combinations of file organization and access mode. Table 18-1 lists these combinations.

Sequential Access Mode

Sequential access mode can be used with any RMS file. Sequential access means that records are retrieved or written in a particular sequence. The organization of the file establishes this sequence.

Sequential Access to Sequential Files

In a sequentially organized file, physical arrangement establishes the order in which records are retrieved when using sequential access mode. To read a particular record in a file, say the fifteenth record, a program must open the file and access the first fourteen records before accessing the desired record. Thus each record in a sequential file can be retrieved only by first accessing all records that physically

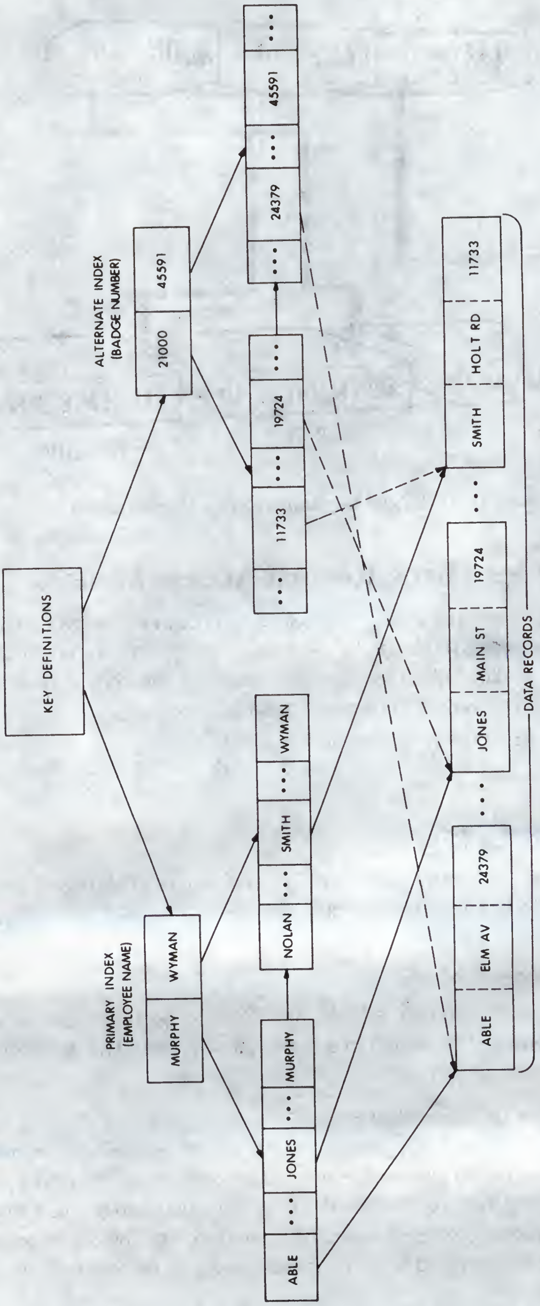


Figure 18-5 Multikey Indexed File Organization

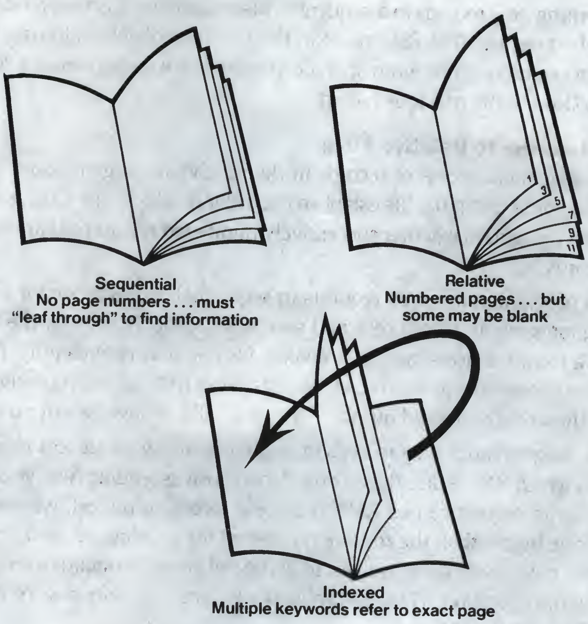


Figure 18-6 Comparison of File Organization Methods

Table 18-1 Permissible Combinations of Access Modes and File Organizations

File Organization	Access Mode			
	Sequential	Random		RFA
		Record #	Key Value	
Sequential	Yes	No	No	Yes*
Relative	Yes	Yes	No	Yes
Indexed	Yes	No	Yes	Yes

*Disk files only.

precede it. Similarly, once a program has retrieved the fifteenth record, it can read all the remaining records (from the sixteenth on) in physical sequence. It cannot, however, read any preceding record without beginning again with the first record.

When writing new records to a sequential file in sequential access mode, a program must first request that RMS position the file immediately following the last record. Then each sequential write operation the program issues causes a record to be written following the previous record.

Sequential Access to Relative Files

During the sequential access of records in the relative file organization, the contents of the record cells in the file establish the order in which a program processes records. RMS recognizes whether successively numbered record cells are empty or contain records.

When a program issues read requests in sequential access mode for a relative file, RMS ignores empty record cells and searches successive cells for the first one containing a record. If, for example, a relative file contains records only in cells 3, 13, and 47, successive sequential read requests cause RMS to return relative record number 3, then relative record number 13, and finally relative record number 47.

When a program adds new records in sequential access mode to a relative file, the order in which RMS writes the records depends on ascending relative cell numbers. Each write request causes RMS to place a record in the cell whose relative number is one higher than the relative number of the previous request, as long as that cell does not already contain a record. If the cell already contains a record, RMS rejects the write operation. Thus, RMS allows a program to write new records only into empty cells in the file.

Sequential Access to Indexed Files

In an indexed file, the presence of one or more indexes permits RMS to determine the order in which to process records in sequential access mode. The entries in an index are arranged in ascending order by key values. Thus, an index represents a logical (rather than physical) ordering of the records in the file. If more than one key is defined for the file, each separate index associated with a key represents a different logical ordering of the records in the file. A program, then, can use the sequential access mode to retrieve records in the order represented by any index.

When reading records in sequential access mode from an indexed file, a program initially specifies a key (primary key, first alternate key, second alternate key, and so on) to RMS. Thereafter, RMS uses the index associated with that specified key to retrieve records in the sequence represented by the entries in the index. Each successive record RMS returns in response to a programmed read request contains a value in the specified key field that is equal to or greater than that of the previous record returned.

In contrast to a sequential read request, sequential write requests to an indexed file do not require the initial key specification. Rather, RMS uses the stored definition of the primary key field to locate the primary key value in each record to be written to the file. When a program issues a series of sequential write requests, RMS verifies that each successive record contains a key value in the primary key field that is equal to or greater than that of the preceding record.

Random Access Mode

In random access mode, the program, rather than the organization of the file, establishes the order in which records are processed. Each program request for access to a record operates independently of the previous record accessed. Associated with each request in random mode is an identification of the particular record of interest. Successive requests in random mode can identify and access records anywhere in the file.

Random access mode cannot be used with sequentially organized files. Both the relative and indexed file organizations, however, permit random access to records. The subsections that follow describe the use of random access with these organizations. Each organization provides a distinct way programs can identify records for access.

Random Access to Relative Files

Programs can read or write records in a relative file by specifying relative record number. RMS interprets each number as the corresponding cell in the file. A program can read records at random by successively requesting, for example, record number 47, record number 11 and, record number 31. If no record exists in a specified cell, RMS returns a nonexistence indicator to the requesting program. Similarly, a program can store records in a relative file by identifying the cell in the file that a record is to occupy. If a program attempts to write a new record in a cell already containing a record, RMS returns a record-already-exists indicator to the program.

Random Access to Indexed Files

The indexed file organization also permits random access of records. However, for indexed files, a key value rather than a relative record number identifies the record.

Each program read request in random access mode specifies a key value and the index (primary index, first alternate index, second alternate index, and so on) that RMS must search. When RMS finds the key value in the specified index, it reads the record that the index entry points to and passes the record to the user program. Under random access the programmer could, for example, instruct RMS to return all records with SMITH in the key-equal-to-last-name field.

In contrast to read requests, which require a program-specified key value, program requests to write records randomly in an indexed file do not require the separate specification of a key value. All key values (primary and, if any, alternate key values) are in the record itself. When an indexed file is opened, RMS retrieves all definitions stored in the file. Thus, RMS knows the location and length of each key field in a record. Before writing a record into the file, RMS examines the values contained in the key fields and creates new entries in the indexes. In this way RMS ensures that the record can be retrieved by any of its key values. Thus, the process by which RMS adds new records to the file is precisely the process it uses to construct the original index or indexes.

Record's File Address (RFA) Access Mode

Record's file address (RFA) access mode can be used with any file organization as long as the file resides on a disk device. This access mode is further limited to retrieval operations only. Like random access mode, however, RFA access allows a specific record to be identified for retrieval.

As the name suggests, every record within a file has a unique address. The actual format of this address depends on the organization of the file. In all instances, however, only RMS can interpret this format.

The most important feature of RFA access is that the address (RFA) of any record remains constant while the record exists in the file. After every successful read or write operation, RMS returns the RFA of the subject record to the program. The program can then save this RFA to use again to retrieve the same record. It is not required that this RFA be used only during the current execution of the program. RFAs can be saved and used at any later time.

Dynamic Access

Dynamic access is not strictly an access mode. Rather, it is the capability to switch from one access mode to another while processing a file. There is no limitation on the number of times such switching can occur. The only limitation is that the file organization (or, in the case of RFA access, the device containing the file) must support the access mode selected.

As an example, dynamic access can be used effectively immediately following a random or RFA access mode operation. When a program accesses a record in one of these modes, RMS establishes a new current position in the file. Programs can then switch to sequential access mode. By using the randomly accessed record (rather than the beginning of the file) as the starting point, programs can retrieve succeeding records in the sequence established by the file's organization.

File Attributes Are Defined at Creation Time.

The logical and physical characteristics of a RMS file are known as its attributes. These characteristics are defined by the source language statements of an application program or by the RMS utility programs DEFINE and DESCRIBE. RMS uses this information about the attributes to structure a file on the storage medium.

The most important attribute of any RMS file is its organization. A file for use in a particular application can be tailored by making the proper selection of this and other attributes. In addition to file organization, the user can choose from among the following attributes:

- Storage medium on which the file resides
- File and protection specification of the file
- Format and size of records
- Size of the file

- Size of a particular storage structure, known as the bucket, within relative and indexed files
- Definition of keys for indexed files

Storage Media

Selection of a storage medium on which RMS builds a file is related to the organization of the file. Permanent sequential files can be created on disk devices or ANSI magnetic tape volumes. Transient files can be written on devices such as lineprinters and terminals. Unlike sequential files, relative and indexed files can reside only on disk devices.

File Specifications

The name assigned to a new file enables RMS to find the file on the storage medium. RMS allows for the assignment of a protection specification to a file at the time it is created.

When a file is created, the user must provide the format and maximum size specifications for the records the file will contain. The specified format establishes how each record appears physically in the file on a storage medium. The size specification allows RMS to verify that records written into the file do not exceed the length specified when the file was created.

RMS Record Formats

RMS record formats include:

- Fixed
- Variable
- Variable-with-fixed-control (VFC)
- Stream

Like the selection of a storage medium, the choice of a format for the records of a file depends on a file's organization. Table 18-2 shows the allowed combinations of record format and file organization.

Fixed Length Record Format

The term "fixed length record format" refers to records of a file that must all be one specified size. Each record occupies an identical amount of space in the file.

Variable Length Record Format

In variable length record format, records in a file can be either equal or unequal in length. To allow retrieval of variable length records from a file, RMS prefixes a count field to each record it writes. The count field describes the length (in bytes) of the record. RMS removes this count field before it passes a record to the program.

Table 18-2 Record Formats and File Organizations

File Organization	Record Format			
	Fixed	Variable	VFC	Stream
Sequential	Yes	Yes	Yes	disk only
Relative	Yes	Yes	Yes	No
Indexed	Yes	Yes	No	No

Variable-with-Fixed-Control Record Format

Variable-with-fixed-control (VFC) records consist of two distinct parts, the fixed control area and the user data record. The size of the fixed control area is identical for all records of the file. The contents of each fixed control area are completely under the control of the program and can be used for any purpose. As an example, fixed control areas can be used to store the identifier (for example, relative record number or RFA) of related records.

The second part of a VFC record is similar to a variable length record. It is a user data record, variable in length and composed of individual data fields.

Stream Format Records

Records in stream format can vary in size. However, no count field precedes each record. Instead, RMS considers the entire file a stream of contiguous ASCII characters. Each record in the file is delimited by one of the following:

- Form feed (FF)
- Vertical tab (VT)
- Line feed (LF)
- Carriage return immediately followed by line feed (CR-LF)

Stream format records are supported for file interchange with non-RMS application programs. Since this format is not very efficient, it should be used only when such interchange is a concern.

Size of Records

The programmer provides RMS with record size information along with the selected record format. RMS use of this information depends on the record format chosen.

When fixed format records are chosen, the actual size of each record in the file must be indicated. This size specification becomes part of the information stored and maintained by RMS for the file. Thereafter, if a program attempts to write a record whose length differs from this specified size, RMS will reject the operation.

When creating a file with variable length format records, you can specify a maximum record size greater than zero or, for sequential and indexed files, a maximum record size equal to zero. If the specified size is greater than zero, RMS interprets the value as the size of the largest record that can be written into the file.

VFC format records require two size specifications. The first size identifies the length of the fixed control area of all records in the file; the second size specification represents the maximum length of the data portion of the VFC records. RMS handles this second size specification in a manner similar to its handling of the size specification for variable format records.

For stream format records, RMS permits the user to specify the same record size information as for variable format records. That is, a nonzero value represents the maximum permitted size of any record written in the file while a zero value suppresses RMS size checking.

Size of RMS Files

The size of an RMS file is expressed as a number of *virtual blocks*. Virtual blocks are physical storage structures. That is, each virtual block in a file is a unit of data whose size depends on the physical medium on which the file resides. The size of virtual blocks in files on disk devices, for example, is 512 bytes.

The operating system assigns ascending numbers to a file's virtual blocks. This numbering scheme allows a file to appear as a series of adjacent virtual blocks. In reality, though, the successive numbering of virtual blocks and the physical placement of these blocks on a storage medium need not correspond.

The virtual blocks of a file contain the records that programs write into the file. Depending on the size of records, a virtual block can contain one record, more than one record, or a portion of a record.

When creating an RMS file, you can specify an initial allocation size. If no file size information is given, RMS allocates the minimum amount of storage needed to contain the defined attributes of the file.

Buckets in Relative and Indexed Files

RMS uses a storage structure known as a *bucket* for building and maintaining relative and indexed files. Unlike a virtual block, a bucket can never contain a portion of a record. That is, RMS does not permit records to span bucket boundaries.

The size of buckets in a file is defined at the time the files are created. A large bucket size will serve to increase sequential mode processing speed of a file, since fewer actual I/O transfers are required to access records. Minimizing bucket size, on the other hand, means that less I/O buffer space is required to support file processing.

Key Definitions for Indexed Files

To define a key for an indexed file, the position and length of character data in the records of the file must be specified. At least one key, the primary key, must be

defined for an indexed file. Additionally, up to 254 alternate keys can be defined. Each primary and alternate key represents from 1 to 255 characters in each record of the file.

When identifying the position and the length of keys to RMS, you can define either simple or segmented keys. A simple key is a single, contiguous string of characters in the record; in other words, a single data field. A segmented key, however, can consist of from two to eight data fields within records. These data fields need not be contiguous, and RMS treats the separate data fields (segments) as a logically contiguous character string.

At file creation time, two characteristics for each key can be specified. Duplicate key values are allowed or the key value can change. If duplicate key values are allowed, the programmer indicates that more than one record in the file can have the same value in a given key.

The personnel file can serve as an example of the use of duplicate keys. At file creation time, the department name field could be defined as an alternate key. As programs wrote records into the file, the alternate index for the department name key field would contain multiple entries for each key value (for example, PAYROLL, SALES, ADMINISTRATION) since departments are composed of more than one employee. When such duplication occurs, RMS stores the records so that they can be retrieved in first-in/first-out (FIFO) order.

An application could be written to list the names of employees in any particular department. A single execution of the application could, for example, list the names of all employees working in the department called SALES. By randomly accessing the file by alternate key and the key value SALES, the application would obtain the first record written into the file containing this value. Then, the application could switch to sequential access and successively obtain records with the same value, SALES, in the alternate key field. Part of the logic of the application would be to determine the point at which a sequentially accessed record no longer contained the value SALES in the alternate key field. The program could then switch back to random access mode and access the first record containing a different value (for example, PAYROLL) in the department name key field.

The second key characteristic (key value can change) indicates that records can be read and then written back into the file with a modified value in the key. When such modification occurs, the appropriate index is automatically updated to reflect the new key value. This characteristic can be specified only for alternate keys. Further, when specifying this characteristic, the user must also specify that the duplicate key values are allowed.

If the sample personnel file were created with the department name field as an alternate key, the creator of the file would need to specify that key values can change. This allows a program to access a record in the file and change the contents of a department name data field to reflect the transfer of an employee from one department to another.

The user can also declare the converse of either of these two key characteristics. That is, the user can specify for a given key that duplicate key values are not allowed or that key values cannot change. When duplicate key values are not allowed, RMS rejects any program request to write a record containing a value in the key that is already present in another record. Similarly, when the key value cannot change, RMS does not allow a program to write a record back into the file with a modified value in the key.

RMS Processes Both Files and Records.

After RMS has created a file according to the user's description of file characteristics, a program can access the file and store and retrieve data. The organization of the file determines the types of record operations permitted.

If the record accessing capabilities of RMS are not used, programs can access the file as a physical structure, in which case RMS considers the file simply as an array of virtual blocks. To process a file at the physical level, programs use a type of access known as *block I/O.*

File Processing

At the file level (that is,independent of record processing) a program can create, open, modify, extend, close, and delete a file. Once a program has opened a file for the first time, it has access to the unique internal ID for the file. If the program intends to open the file subsequently, it can use the internal ID to open the file. This avoids spending time on a directory search.

Directory Operations

RMS directory operations affect only directory entries, not the actual contents of the files. Directory operations include:

- ENTER— create a directory entry
- REMOVE—delete a directory entry
- RENAME—replace a directory entry
- PARSE—analyze a file specification
- SEARCH—search directories

On RSTS/E, the directory operations are RENAME, PARSE, and SEARCH.

File Operations

File operations affect files as whole entities rather than individual records or blocks in files. The file operations are:

- CREATE—create a file (with a corresponding dictionary entry) and open the file for processing
- OPEN—open an existing file for processing
- DISPLAY—write file information to control blocks

- ERASE—delete file contents (records or blocks) and remove dictionary entry
- EXTEND—increase the allocation for a file
- CLOSE—close an open file

Record Operations on RMS Files

The organization of a file, defined when the file is created, determines the types of operations that the program can perform on records. Depending on file organization, RMS permits a program to perform the following record operations:

- Read a record—RMS returns an existing record within the file to the program.
- Write a record—RMS adds a new record that the program constructs to the file. The new record cannot replace an already existing record.
- Find a record—RMS locates an existing record in the file. It does not return the record to the program, but establishes a new current position in the file.
- Update a record—The program modifies the contents of a record read from the file. RMS writes the modified record into the file, replacing the old record.

Sequential File Organization Record Operations

In sequential file organization, a program can read existing records from the file using sequential or RFA access modes. New records can be added only to the end of the file and only through the use of sequential access mode. The find operation is supported in both sequential and RFA access mode. In sequential access mode, the program can use a find operation to skip records. In RFA access mode, the program can use the find operation to establish a random starting point in the file for sequential read operations. The sequential file organization does not support the delete operation, since the structure of the file requires that records be adjacent in and across virtual blocks. A program can, however, update existing records in disk files as long as the modification of a record does not alter its size.

Relative File Organization Record Operations

Relative file organization permits programs greater flexibility in performing record operations than does sequential organization. A program can read existing records from the file using sequential, random, or RFA access mode. New records can be sequentially or randomly written as long as the intended record cell does not already contain a record. Similarly, any access mode can be used to perform a find operation. After a record has been found or read, RMS permits the delete operation. Once a record has been deleted, the record cell is available for a new record. A program can also update records in the file. If the format of the records is variable, update operations can modify record length up to the maximum size specified when the file was created.

Indexed File Organization Record Operations

Indexed file organization provides the greatest flexibility in performing record operations. A program can read existing records from the file in sequential, RFA, or

random access mode. When reading records in random access mode, the program can choose one of four types of matches that RMS must perform using the program-provided key value. The four types of matches are:

- Exact key match
- Approximate key match
- Generic key match
- Approximate and generic key match

Exact key match requires that the contents of the key in the record retrieved precisely match the key value specified in the program read operation.

The approximate match facility allows the program to select either of two relationships between the key of the record retrieved and the key value specified by the program. These are equal to or greater than, or greater than. The advantage of this kind of match is that if the requested key value does not exist in any record of the file, RMS returns the record that contains the next higher key value. This allows the program to retrieve records without knowing an exact key value.

Generic key match means that the program need specify only an initial portion of the key value, thereby forming a logical truncation upon the key. RMS returns to the program the first occurrence of a record whose key contains a value beginning with those characters. This capability is useful in applications where a series of records must be retrieved according to the contents of only a part of the key field. In an indexed inventory file, for example, a company might designate its part numbers in such a way that the first three digits represent the vendor from whom the part is purchased. In order to retrieve the record associated with a particular part, the program would normally supply the entire part number. Generic selection permits the retrieval of the first record representing parts purchased from a specific vendor.

The final type of key match combines both generic and approximate facilities. The program specifies only an initial portion of the key value, as with generic match. Additionally, a program specifies that the key data field of the record retrieved must be either equal to or greater than the program-supplied value or greater than the program-supplied value.

In addition to versatile read operations, RMS allows any number of new records to be written into an indexed file. It rejects a write operation only if the value contained in a key of the record violated a user-defined key characteristic (for example, duplicate key values not permitted).

The find operation, similar to the read operation, can be performed in sequential, RFA, or random access mode. When finding records in random access mode, the program can specify any one of the four types of key matches provided for read operations.

In addition to read, write, and find operations, the program can delete any record in an indexed file and update any record. The only restriction RMS applies

during an update operation is that the contents of the modified record must not violate any user-defined key characteristic (e.g., key values cannot change and duplicate key values are not permitted).

Block I/O

Block I/O allows a program to bypass the record processing capabilities of RMS entirely. Rather than performing record operations through the use of supported access modes, a program can process a file as a physical structure consisting solely of virtual blocks.

Using block I/O, a program reads or writes multiple virtual blocks by identifying a starting virtual block number in the file. Regardless of the organization of the file, RMS accesses the identified block or blocks on behalf of the program.

Because RMS files, particularly relative and indexed files, contain internal information meaningful only to RMS itself, Digital does not recommend that a file be modified by using block I/O. The presence of the block I/O facility, however, does permit user-created file structures. The resultant structures must be user-maintained using specialized programs. The structures cannot be accessed using RMS record access mode and record operations.

RMS Runtime Environment Has Two Levels.

The environment within which a program processes RMS files at runtime consists of two levels: the file processing level and the record processing level.

At the file processing level, RMS and the host operating system provide an environment that permits concurrently executing programs to share access to the same file. RMS ascertains the amount of sharing permissible from information provided by the programs themselves. RMS also provides facilities that allow programs to minimize buffer space requirements for file processing.

At the record processing level, RMS allows programs to access records in a file through one or more record access streams. Each record access stream represents an independent and simultaneously active series of record operations directed toward the file. Within each stream, programs can perform record operations synchronously or asynchronously on operating systems that support this facility. That is, RMS allows programs to choose between receiving control only after a record operation request has been satisfied (synchronous operation) or receiving control before the request has been satisfied (asynchronous operation).

For both synchronous and asynchronous record operations, RMS provides two record transfer modes, move mode and locate mode. Move mode causes RMS to copy a record from an I/O buffer into a program-provided location. Locate mode allows programs to address records directly in an I/O buffer.

If your system has suitable DECnet facilities, RMS offers file and record access to files residing on other network nodes, providing the other nodes have an RMS-based File Access Listener (FAL). Generally, remote access is indistinguishable from local access. However, certain functions cannot be executed remotely. These

include wildcard support, $PARSE, $SEARCH, $ENTER, $REMOVE, $RENAME, and transmission of device, directory, and file identifiers.

The Processing Environment Allows Executing Programs to Share Files.

RMS provides two major facilities at the file processing level, file sharing and buffer handling.

File Sharing

Timely access to critical files requires that more than one concurrently executing program be allowed to process the same file at the same time. Therefore, RMS allows executing programs to share files rather than requiring them to process files serially. The manner in which a file can be shared depends on the organization of the file. Program-provided information further establishes the degree of sharing of a particular file.

File Organization and Sharing

With the exception of magnetic tape files, which cannot be shared, every RMS file can be shared by any number of programs that are reading, but not writing, the file. Sequential files on disk can be accessed by a single writer or shared by multiple readers. Relative and indexed files, however, can be shared by multiple readers and multiple writers.

Program Sharing

A file's organization establishes whether it can be shared for reading with a single writer or for multiple readers and writers. A program specifies whether such sharing actually occurs at run time. The user controls the sharing of a file through information the program provides RMS when it opens the file. First, a program must declare what operations it intends to perform on the file. Second, a program must specify whether other programs can read the file or both read and write the file concurrently with that program.

The combination of these two types of information allows RMS to determine if multiple user programs can access a file at the same time. Whenever a program's sharing information is compatible with the corresponding information another program provides, concurrent access is allowed.

Bucket Locking

RMS uses a bucket locking facility to control operations to a relative or indexed file that is being accessed by one or more writers. The purpose of this facility is to ensure that a program can add, delete, or modify a record in a file without another program's simultaneously accessing the same record.

When a program opens an indexed or relative file with the declared intention of writing or updating records, RMS locks any bucket accessed by the program. This locking prevents another program from accessing any record in the bucket until the

program releases it, and remains in effect until the program accesses another bucket. RMS then unlocks the first bucket and locks the second.

Buffer Handling

To a program, record processing under RMS appears as the movement of records directly between a file and the program itself. Transparently to the program, however, RMS reads or writes virtual blocks or buckets of a file into or from internal memory areas known as I/O buffers. Records within these buffers are then made available to the program.

In addition to buffers that contain virtual blocks or buckets, RMS requires a set of internal control structures to support file processing. The combination of these buffers and control structures is known as the space pool.

Programmers Access Records through the RMS Record Processing Environment.

After opening a file, a program can access records in the file through the RMS record processing environment. This environment provides three facilities:

- Record access streams
- Synchronous or asynchronous record operations
- Record transfer modes

Record Access Streams

In the record processing environment, a program accesses records in a file through a record access stream, a serial sequence of record operation requests. For example, a program can issue a read request for a particular record, receive the record from RMS, modify the contents of the record, and then issue an update request that causes RMS to write the record back into the file. The sequence of read and update record operation requests can then be performed for a different record, or other record operations can be performed, again in a serial fashion. Thus, within a record access stream, there is at most one record being processed at any time. However, for relative and indexed files, RMS permits a program to establish multiple record access streams for record operations to the same file. The presence of such multiple record access streams allows programs to process in parallel more than one record of a file. Each stream represents an independent and concurrently active sequence of record operations. Further, when such streams update records in the file, RMS employs the same bucket locking mechanism among streams that it uses to control the sharing of a file among separate programs.

Synchronous and Asynchronous Record Operations

Within each record access stream, a program can perform any record operation either synchronously or asynchronously. (The RSTS/E operating system supports synchronous record operations only.) When a record operation is performed synchronously, RMS returns control to a program only after the record operation

request has been satisfied (for example, a record has been read and passed to one program). When a record operation is performed asynchronously, RMS can return control to one program before the record operation request has been satisfied. A program, then, can utilize the time required for the physical transfer between the file and memory of the block or bucket containing the record to perform other computations. However, a program cannot issue a second record operation through the same stream until the first record operation has completed. To ascertain when a record operation has actually been performed, a program can issue a wait request and regain control when the record operation is complete.

Record Transfer Modes

In addition to specifying synchronous or asynchronous operations for each request in a record access stream, a program can utilize either of two record transfer modes to gain access to each record in memory:

- Move Mode Record Transfers—RMS permits move mode record operations for all file organizations and record operations. Move mode requires that an individual record be copied between the I/O buffer and a program. For read operations, RMS reads a block or bucket into an I/O buffer, finds the desired record within the buffer, and moves the record to a program-specified location.

  Before a write or update operation in move mode, the program builds or modifies a record in its own work space. Then the program issues a write or update record operation request, and RMS moves the record to an I/O buffer.

- Locate Mode Record Transfers—RMS supports locate mode record transfers for read operations to all file organizations. However, it permits locate mode on write operations for sequential files only.

  Locate mode reduces the amount of data movement, thereby saving processing time. This mode enables programs to access records directly in an I/O buffer. Therefore, there is normally no need for RMS to copy records from the I/O buffer to a program. To allow the program to access a record in the I/O buffer, RMS provides the program with the address and size of the record in the I/O buffer.

Utilities Aid in RMS Development.

A host of RMS utilities help system managers and operators develop record management services. The following summarizes those utilities available.

File Design Utility (RMSDES)

The File Design Utility lets you interactively design and create RMS-11 files that contain data records.

Index File Load Utility (RMSIFL)

This utility reads records from any type of RMS-11 file and loads them into an

indexed file created especially to store those records. RMSIFL also compresses indexed files and converts ASCII stream files to RMS-11 indexed files.

File Conversion Utility

File Conversion reads records from an RMS-11 file of any type and loads them into another RMS-11 file of any type. File conversions can also take place over networks on operating systems with DECnet network capabilities and Data Access Protocol (DAP) support.

File Back-Up Utility (RMSBCK)

This utility copies the contents of any RMS-11 disk file to another disk, or to a mag-tape container file created for back-up purposes.

File Display Utility (RMSDSP)

This utility provides a concise description of any RMS-11 file, including backup container files.

File Restoration Utility (RMSRST)

The File Restoration Utility restores to disk those files that were backed up on magnetic tape or disk by the Back-Up Utility. This utility allows for selective restoration of any account to which you have access privileges, and includes features providing data integrity checks, which let you check the reliability of the restored data files. In addition, it provides for back-up and restore intersystem transportability.

Chapter 19
DATATRIEVE-11

DATATRIEVE-11 Puts Information at Your Fingertips.

DATATRIEVE-11 is a data maintenance, inquiry, and report writing system available in the PDP-11 family on RSX-11M-PLUS, RSX-11M, RSTS/E, and IAS operating systems. It provides users with direct, fast, easy access to the data in sequential, indexed, and relative RMS-11 files. DATATRIEVE-11 accepts simple words and phrases to extract, modify, or update RMS-11 data. With fewer than ten commands, users can find, print, update, and sort records.

By eliminating the need for many specialized application programs and their time-consuming compilations, DATATRIEVE-11 helps to maximize programmer and system productivity. And thanks to its familiar syntax, DATATRIEVE-11 is easy to learn and simple to use. You can access data without the services of a programmer. In addition, it immediately notifies you of any errors, so that you can correct them immediately. DATATRIEVE-11 makes file access simple, while maintaining the file security provided by the operating system.

Designed to be used by both novices and computer professionals, DATATRIEVE-11 operates effectively in commercial, technical, scientific, industrial, or educational environments. Typical applications range all the way from producing a complex report to answering a casual question. For example, using DATATRIEVE-11, a personnel file could be queried to determine how many employees held bachelor's degrees, or the same file could be used to produce a report with a complete statistical analysis of the employee education versus compensation.

Another typical environment where DATATRIEVE-11 would be useful is a distributorship with an order processing system. In this setting, sales data could be extracted by territory. Order backlogs might be retrieved, sorted by supplier, and printed on a report.

Additional facilities are provided by the system for selective data retrieval, sorting, formatting, updating, and report generation.

DATATRIEVE-11 Helps You Produce Detailed Reports.

There are many advantages to using DATATRIEVE-11 over application programs when generating ad hoc queries and reports. The three major categories of DATATRIEVE-11 capabilities are:

- Data Access and Update Facilities
- Report Generation Facilities
- Data Dictionary Facility

Data Access and Update Facilities

The INQUIRY (data access) and UPDATE commands provided by DATATRIEVE-11 let you manipulate records and files. DATATRIEVE-11 offers simple and advanced commands. Simple commands enable the novice to find, update, and sort records. Advanced commands can be used to perform more complex functions such as combining commands to form procedures.

DATATRIEVE-11 provides the first-time user with flexible "value-based" data access/update capabilities that can eliminate the need for programming overhead in many situations. Information is returned to the user in the form of collections of records that can be manipulated and/or displayed on the terminal or printer using the DATATRIEVE-11 report writing facility. Several specific features bring this power to users.

- GUIDE MODE is a tutorial aid with automatic prompting. This feature permits the novice to retrieve and display data by stepping through a subset of commands.
- The documentation set for DATATRIEVE-11 includes a Primer designed to introduce the novice to the use of DATATRIEVE-11, and a User's Guide that uses examples to present the various DATATRIEVE-11 functions.
- The commands are simple words and phrases instead of confusing acronyms.
- DATATRIEVE-11 supports simple arrays.
- A data type is provided that recognizes data formats and facilities, entering and displaying data in any one of several formats.
- DATATRIEVE-11 provides a full set of arithmetic operators (addition, subtraction, multiplication, division, and negation), statistical operators (total, average, maximum, minimum, and count), and conversion between data types used in Digital's FORTRAN, COBOL, DIBOL, and BASIC-PLUS-2 languages.

Report Generation

In addition to its inquiry and update commands, DATATRIEVE-11 provides a report writing facility to generate reports from RMS-11 files. The data can come

directly from the files or can be preselected and manipulated through a series of DATATRIEVE-11 commands. Users can specify such parameters as spacing, titles, headings, and totals on their reports. As in the inquiry and update facility, errors in commands are discovered immediately to avoid printing wrong or incomplete reports.

When reporting requirements change, you need not rewrite or modify an entire reporting program. All you do is issue modified statements to the report facility. The DATATRIEVE-11 report writer provides easy-to-use commands to control the following report functions:

- Report name, date, and page numbering
- Page width and length specification
- Detail line specification
- Multiple control break specification with automatic totaling at any level
- Multiple report sections
- Statistical lines—such as total, average and count

A DATATRIEVE-11 report command can be freely intermixed with other DATATRIEVE commands.

Data Dictionary Facility

The Data Dictionary maintains definitions of record structures and domain names. A record structure describes the format of the records in the file. A domain is a named group of data containing records of a single type. Record structures and domain names must be defined before DATATRIEVE-11 can be used to access data.

The definitions provide a substantial level of data and program independence because the definitions (or views) can cross file boundaries. Thus, by providing a single value-based DATATRIEVE-11 query, users can access information from multiple files and records. DATATRIEVE-11 also provides commands to list the contents of the Data Dictionary, to delete entries, and to control access to individual entries.

DATATRIEVE-11 Commands Let You Store, Update, and Retrieve Information.

DATATRIEVE-11 is a multifaceted data management facility that uses a set of English commands for data retrieval, modification, display, and report generation. Prompting is automatic for both command and data entry. The major commands include:

- HELP— provides a summary of each DATATRIEVE-11 command
- READY— identifies a domain for processing and controls the access mode to the appropriate file

- FIND— establishes a collection (subset) of records contained in either a domain or a previously established collection based on a Boolean expression
- SORT— re-orders a collection of records in either the ascending or descending sequence of the contents of one or more fields in the records
- PRINT— prints one or more fields of one or more records. Output can optionally be directed to a lineprinter or disk file. Format control can be specified. A column header is generated automatically
- SELECT— identifies a single record in a collection for subsequent individual processing
- MODIFY— alters the values of one or more fields for either the select record or all records in collection. Replacement values are prompted for by name
- STORE— creates a new record. The value for each field contained in the record is prompted for by name, or indicated on a predefined form
- ERASE— deletes one or more records from the RMS-11 file corresponding to the appropriate domain
- FOR— executes a subsequent command once for each record in record collection, providing a simple looping facility
- DECLARE— defines global and local variables to be used within a DATATRIEVE-11 query
- DEFINE— provides a consistent mechanism for creating domain, record, table, procedure, and view definitions in the DATATRIEVE-11 Data Dictionary
- EDIT— invokes an editor that inserts, modifies, or deletes text from the DATATRIEVE-11 Data Dictionary

In addition to the simple data manipulation commands, a number of more complex commands are available for the advanced user. These commands, such as REPEAT, BEGIN-END, and IF-THEN-ELSE, may be used to combine two or more DATATRIEVE-11 commands into a single compound command. These, in turn, may be stored in the Data Dictionary as procedures for invocation by less experienced users.

DATATRIEVE-11 can be used interactively from a terminal or in batch mode.

Data Definition

The data definition process involves establishing special DATATRIEVE-11 constructs called *domains*. The domain concept is central to DATATRIEVE-11. Domains represent relationships between actual physical data and descriptions of data. DATATRIEVE-11 performs all data management in terms of domains. Domains must be defined before DATATRIEVE-11 can manage the data associated with them.

In the simplest form, a DATATRIEVE-11 domain definition consists of a domain name, the name of the RMS-11 file, and the name of a record format description. A record format description defines the fields within a record, assigning each field a

name and specifying its length, data type, and other vital parameters. All DATATRIEVE-11 domain definitions and record format descriptions are contained in the DATATRIEVE-11 Data Dictionary.

Record format descriptions can specify data validation criteria on a per-field basis. DATATRIEVE-11 automatically uses the validation parameters to screen data at the time of input so that only data defined as valid is accepted. Supported validation parameters include range checks and must-match tables.

Domains can span multiple RMS-11 files and can also include the name of an associated DATATRIEVE-11 table.

Data Management

Data management involves creating and maintaining data in a current and correct state by adding, eliminating, and modifying records. The STORE, ERASE, and MODIFY statements are used to perform these relatively straightforward functions.

When an application requires the creation of new files, the files must be filled with data. This process is called "populating" the file. A series of successive STORE statements is used for this purpose. With the STORE statement, DATATRIEVE-11 prompts the user for each field value and, before accepting input, performs any validation checks specified by the record format description.

Data Retrieval

Maintaining an accurate database, however, is not an end in itself. Data is used to make decisions, generate reports, initiate transactions, and generally facilitate the operational processes of an enterprise. DATATRIEVE-11 allows stored data to be retrieved in an easily understood form regardless of the underlying data structure.

The data retrieval statements of DATATRIEVE-11 are simple and particularly powerful statements. They consist of verbs modified by a Record Selection Expression (RSE). The RSE defines a subset of the records in the domain. These records are then selected by DATATRIEVE-11 for retrieval. One statement can get the answer to a casual query or produce a long detailed report.

"EMPLOYEES WITH SALARY GREATER THAN $20,000," "ACCOUNTS WITH UNPAID-BALANCE GREATER THAN $600," or "DONORS WITH BLOOD TYPE EQUAL O-NEG" are examples of typical RSEs. Multiple conditions can be combined in a single RSE—for example, "DONORS WITH BLOOD TYPE EQUAL O-NEG AND LAST DONATION DATE LESS THAN JANUARY 1982." The DATATRIEVE-11 SORT operator can be appended to the RSE to order the records being retrieved.

Ad hoc information retrieval with DATATRIEVE-11 is normally performed as an iterative process using a series of statements to progressively narrow down the group of records to be retrieved. This works by using a FIND request with a specified domain as its object to establish what is called the current collection. Subsequent FIND requests progressively narrow down the current collection until the user is satisfied with the results. For example, the statement "FIND DONORS WITH

BLOOD TYPE EQUAL O-NEG AND LAST DONATION DATE LESS THAN JANUARY 1981" might yield the DATATRIEVE-11 response "200 RECORDS FOUND." In this case, the user could narrow down the current collection with the statement "FIND CURRENT WITH ZIP-CODE EQUAL 77451." DATATRIEVE-11 might then respond with "14 RECORDS FOUND" and the user could print these records to get telephone numbers for soliciting blood donations to help an accident victim.

Reports

The PRINT statement is used to output information to a display terminal, a printer, or a RMS-11 file. Though there are some formatting options possible with the PRINT statement, they are limited. The REPORT command provides a more comprehensive set of formatting options for producing standard printed reports with page and column headings, page numbers, totals, and subtotals.

Stored Procedures

With the DEFINE PROCEDURE command, users can define sequences of DATATRIEVE-11 commands and statements and store them for later use. PROCEDURES can be invoked to be run by themselves or can be embedded in other sequences of commands and statements.

DATATRIEVE-11 is Easy to Use.

DATATRIEVE-11 ease of use features include a guide mode, an editor, and an *Application Design Tool.*

Guide Mode

DATATRIEVE-11 provides a self-teaching facility for use with VT52 and VT100 family terminals called *guide mode*. In this mode of operation, users are guided through their DATATRIEVE-11 sessions with a series of prompts.

To invoke guide mode, the user issues a SET GUIDE command. DATATRIEVE-11 immediately responds with "ENTER COMMAND, TYPE ? FOR HELP." If "?" is typed at this point, DATATRIEVE-11 will present the user with the possible responses—in this case, READY, SHOW, or LEAVE. If one of the alternatives is selected, DATATRIEVE-11 then proceeds to guide the user through the syntax of the selected statement. In the case of READY, DATATRIEVE-11 prompts with "DOMAIN NAME, END WITH SPACE."

DATATRIEVE-11 Editor

The DATATRIEVE-11 editor is a subset of the Digital standard editor, EDT. It can be used only in line mode and can edit only definitions stored in the DATATRIEVE Data Dictionary.

Application Design Tool

The Application Design Tool (ADT) is a DATATRIEVE-11 utility that simplifies the process of defining domains, record formats, and creating RMS-11 data files. Operating in an interactive mode, ADT presents the user with a series of simple ques-

tions. The user's responses provide ADT with information to generate the proper definitions. For RMS-11 files, ADT will prompt the user to get a full set of parameters pertaining to organization, index keys, etc. ADT will then create an indirect command file that the user can execute immediately or at some later time to create the desired file.

DATATRIEVE-11 Comes with Advanced Features, Too.

DATATRIEVE-11 allows domains to be defined that can subset the fields of a record and can span multiple RMS-11 files. These are called *view domains* because they provide a user's logical view of the data. Once view domains have been established, they can be used in much the same way as simple domains.

This facility is basic to high-level data access. It makes it possible for a single statement to retrieve a set of related records. For example, in an employee records application there might be an employee master file with company confidential information pertaining to salary that could be masked out during a view domain. Other information in the master file such as addresses and telephone numbers could then be combined in another view domain with a special file of records used in a car-pooling application.

View domains can also be used with RMS-11 files for domains containing records related in a hierarchical fashion. For example, in an order processing application there might be an account master file and an order file. These files could be combined in a view to produce billing statements with data drawn from both files. A single record in this view domain could be defined to contain one account master record and all the orders applying to that account.

DATATRIEVE-11 *tables* can be defined to reside in the DATATRIEVE-11 Data Dictionary. Tables can be used as a must-match list for field validation, or for argument function type conversions. For instance, a must-match list of valid U.S. Postal Service state abbreviations could be used to check an address field or an argument function table could be used to convert from state abbreviation codes to the spelled out state name.

DATATRIEVE-11 Has its Own Protection System.

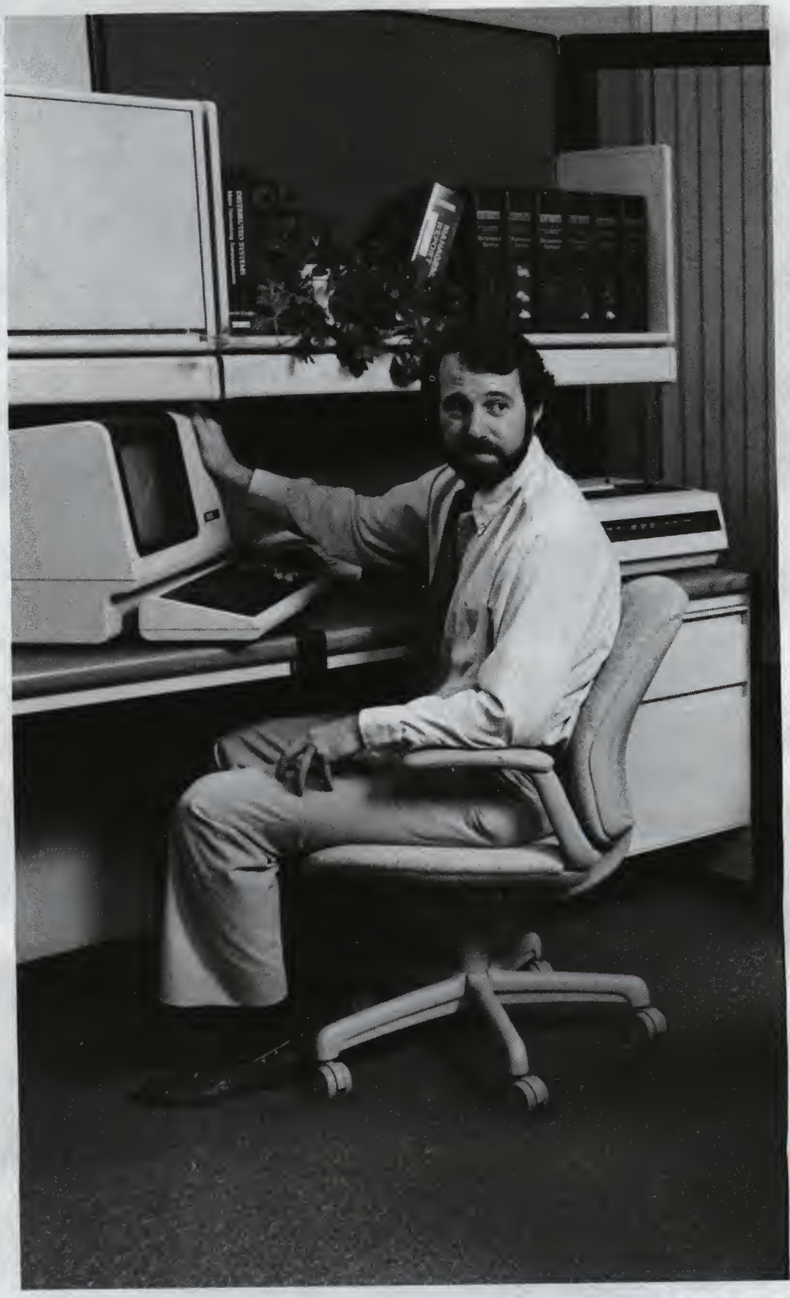
Data protection is accomplished through two independent mechanisms: the protection systems of the host operating system and those within DATATRIEVE-11. The DATATRIEVE-11 protection system uses passwords and User Identification Codes (UICs or PPNs) to allow a user to regulate access to domains, records, procedures, and tables through access requirements recorded in the Data Dictionary. Thus, each resource has its own security system to assure access is not granted to unauthorized users.

DATATRIEVE-11 Version 3 Offers Users a Full Range of Data Access.

The latest edition of DATATRIEVE-11 is version 3, which is well suited to low-cost, multiuser systems such as the MICRO/PDP-11. Version 3 gives users access to data not only on their own systems but on departmental or corporate PDP-11 and VAX systems as well. Users at all levels can also write entire applications exclusively in DATATRIEVE.

DATATRIEVE-11 Version 3 features:

- A new distributed information management facility that allows access to DATATRIEVE domains on a PDP-11 system from a VAX system via DECnet. As a result, VAX users can transparently access data, whether on their own system, another VAX, or a PDP-11 running DATATRIEVE.
- A new Remote Call Interface that allows PDP-11 users to access domains on other PDP-11s or VAXes. Users can write programs in COBOL, BASIC, or FORTRAN to access remote DATATRIEVE domains.
- A new DROP statement that allows users to drop selected records from a collection. Users can use DROP to refine a collection until it contains exactly the records they want.
- A startup command file capability that provides users with a means of executing DATATRIEVE commands and statements automatically, everytime they call DATATRIEVE.
- A capability for users to store comments as well as definitions in the Data Dictionary when defining dictionary objects.
- Improved disk space for Data Dictionaries as a result of reduction of record and bucket size.
- Conversion of hyphens to underscores for greater compatibility with VAX DATATRIEVE.



Chapter 20

The EDT Editor

EDT is Powerful, Yet Easy to Learn.

EDT is a powerful text editor available on many Digital operating systems. Though you can use EDT at a variety of terminals, it is especially powerful when used on VT52 and VT100 video terminals, because it can take advantage of the editing keypad that these terminals offer. With keypad mode, a single keystroke performs an entire editing function—for example, deleting or reinserting or replacing a word. You can even redefine the functions of keypad keys (through key macros) to produce commonly needed operations. EDT provides a wide range of benefits to anyone who has to do editing work—including file creation—on a computer.

First, it is very easy to learn. Editing instructions are English words or their shortest unique abbreviations. The order of operands is logical for English syntax; parameters can be either line numbers in the text file or character strings that you choose. Extensive facilities remind you quickly of the possible options for a particular command and of the format for that editing instruction. You can get help on general EDT operations by typing HELP. If you need help while in keypad mode, pressing the HELP key displays information that is specific to keypad editing

Second, the editor protects your editing session with a journaling capability. EDT makes a record of everything you type so that your work will not be lost if your editing session is terminated by equipment failure. In addition, the editing session does not alter the original file until you are sure that you have done what you want. Instead, all editing activity takes place upon a copy of the original file in a temporary workspace called a buffer. A buffer is a part of EDT's memory that can hold an essentially unlimited amount of text. Only when you have ended the session do you have to determine whether or not to incorporate your editing activities into the file.

EDT is capable of working with many files at once. If you want to concatenate several files, create several files from one, or distribute part of a file among many others, you can do so with EDT.

In change mode on a VT52 or VT100 terminal you edit one 22-line window (screenful) at a time so that you can observe immediately the effects of any editing operations you perform. Instead of being restricted to the most recently altered line, you can see a whole screenful of text, and see the relationship of new and old lines. Of course, if the text is longer than 22 lines, you can easily scroll through it to get to any point you want to edit.

EDT Gives You a Choice of Editing Methods.

With EDT you have a choice of keypad or line mode editing. These modes of editing allow you to:

- Display a range of lines
- Find, substitute, insert, and delete text
- Move, copy, and renumber lines
- Copy text into a buffer and write it on files
- Define the functions of keys

Keypad editing is available on VT52 and V100 terminals. You use the group of keys at the right of the keyboard to enter keypad functions. Keypad editing is powerful and versatile, yet it is easy to learn and to use. In keypad editing, the active buffer is displayed on the screen as you edit. You can see the changes you make to a buffer as they take place. There are a wide variety of keypad editing functions, each of which requires you to press only one or two keypad keys to perform a function. You enter commands, insert text, and perform control functions from the keyboard.

Line editing is useful for those who have hardcopy terminals or who prefer editing by numbered lines. In line editing, you make all entries from the keyboard. As you make changes to the contents of the buffer, EDT displays one or more lines at a time.

Keypad Layout

Keypad functions let you perform a variety of operations with a single keystroke. You can change the function of any keypad key to meet your needs with the DEFINE KEY command. Figure 20-1 shows the keypad for a VT100.

Editing Operations

EDT lets you position the cursor, insert and delete text, reposition blocks of text within a file, creat auxiliary files, and more. The combination of a clear and readable video display screen and the extensive keypad functions supported by the VT52 and VT100 terminals, makes editing quick and easy.

Cursor Positioning

You move the cursor around on the screen to position it properly for inserting or modifying text. The cursor can go in any direction. The arrows at the top of the VT100 keyboard, for example, can move the cursor to the right or left by any number of characters. It can be moved up or down by any number of lines. In addition, special function keys on the keypad move the cursor to the right or left by one word or one character, to the beginning or end of a line, or to the beginning or end of the buffer.

You can also move the cursor through a buffer by specifying a character string that will serve as the object of a search. EDT then moves the cursor backward or forward directly to that point. The entire buffer is always available for editing; you may scroll forward or backward through the buffer at will.

NOTE: THE NUMBERS IN THE UPPER LEFT CORNER OF THE KEYS ARE WHAT ACTUALLY APPEAR ON THE KEYS.

Common Keyboard Functions

Backspace	Go to beginning of line
Delete	Delete character
Linefeed	Delete to start of word
CTRL/A	Compute tab level
CTRL/D	Decrease tab level
CTRL/E	Increase tab level
CTRL/K	Define key
CTRL/T	Adjust tabs
CTRL/U	Delete to start of line
CTRL/W	Refresh screen
CTRL/Z	Return to line mode

Figure 20-1 EDT VT100 Keypad

Inserting and Deleting Text

There are several ways to insert and delete text in a buffer. You enter text by typing alphanumeric and special characters at the keyboard. You can delete a single character, a word, or a line, and multiple words and lines backward and forward relative to the cursor by using keypad functions. Furthermore, text deleted during the current editing session can be restored by using the UNDELETE keys to recall it from special buffers reserved for that purpose. This allows quick recovery from editing mistakes or mistyped commands. You can also combine insert and delete operations by using the special keypad functions for finding and substituting text.

Moving Text

Special function keys on the keypad allow you to mark off an entire section of text and then move it to a new position in the file, or string it together with other sections similarly marked off.

Creating Auxiliary Files

From EDT's change mode you have access to EDT's line mode commands, including the WRITE and INCLUDE commands, which allow you to read and write files during an editing session.

Chapter 21

Screen Formatters

FMS-11 Provides Sophisticated Screen Formatting to Applications.

There are numerous instances of commercial, scientific, and industrial applications in which a formatted video screen makes the application so much easier to use. Clerks updating inventory lists, for example, can use a well-designed form to guarantee that the proper part codes, quantities, prices, suppliers, and other pertinent data are all entered exactly as required by the program that is manipulating them. Rather than presenting the clerk with a blank screen and a complicated menu of instructions for entering the data, a form-managed video terminal supplies pictures that automatically indicate where each field goes, instantly checks to see that it is filled with the right number and types of characters, and aids the clerk with concise messages appropriate to the field or to the form as a whole.

Such forms can be extremely simple, or they can be quite complex, depending on the necessities of the program that uses the information being formatted. A chain of related forms might be required in some applications.

FMS-11 Forms Management System provides sophisticated screen formatting for application programs. By using FMS-11, it is easy to create and update video forms with the VT52 and VT-100 families of terminals. FMS-11 allows nonprogrammers to design forms interactively, right on the video screen, without first drafting the form on paper. It eliminates tedious editing and recompiling of a forms program to see whether the form is satisfactory. Users appreciate the easy-to-learn keypad-operated editor, and the HELP facility. Users also like the extensive field protection and validation features that help prevent typing errors.

FMS-11 software supports a variety of standard programming languages under the major PDP-11 operating systems. Also, forms developed for PDP-11 systems can be run without any conversion on VAX/VMS systems using VAX FMS.

FMS-11 makes it easy to use the distinctive video attributes of the VT52 and VT100: reverse video, bold, blink, underline, 132-column lines, jump or smooth scrolling, split or reverse screen. In addition, character data types within fields (pictures) are checked on a character-by-character basis. Furthermore, special symbols

used for formatting can be imbedded within a field without breaking the field into smaller fields. And, programs are coded to be completely independent of the forms layout, since form and field names are not bound to the program until execution time.

Programmer benefits include:

- Easy, interactive design and maintenance of video forms and application programs
- Field and record-level I/O calls
- Reduced memory usage
- Increased application flexibility
- Supported languages: BASIC-11, BASIC-PLUS-2, COBOL-81, FORTRAN-IV, FORTRAN-77, DIBOL-11, and MACRO-11
- Supported PDP-11 operating systems: RT-11, RSX-11M, RSX-11M-PLUS, and RSTS/E.

User benefits include:

- Keypad-operated editor to speed training and use
- Field access by name for complete rearrangement of a form without changing the application program
- Extensive field protection and validation to help prevent errors
- Online help for every field and every form, reducing documentation and training

Description

FMS-11 is a set of utilities and subroutines that provide flexible screen formatting for applications written in assembler or high-level languages. A special purpose interactive editor is used to create FMS-11 form definitions for display on the VT52 and VT100 family of terminals (VT100, VT101, VT102, and VT125). The Form Utility provides a means for maintaining disk-resident form libraries, creating listings or object modules of forms descriptions, and listing directories. Application programs control the operator's interaction with the form by subroutine calls to the FMS-11 Form Driver subroutine library.

FMS-11 Forms

An FMS-11 form is a video screen image composed of data fields with protection, validation information, and constant background text. The data fields and background text can be highlighted using VT52 and VT100 video attributes such as reverse video, underlining, blinking, and bold characters. Split screen and scrolling capabilities permit users to view more data than can be displayed on the screen at one time.

Figure 21-1 shows a sample of a screen form generated by the Form Editor and demonstrates the use of various display attributes, such as reverse, bold, and underline:

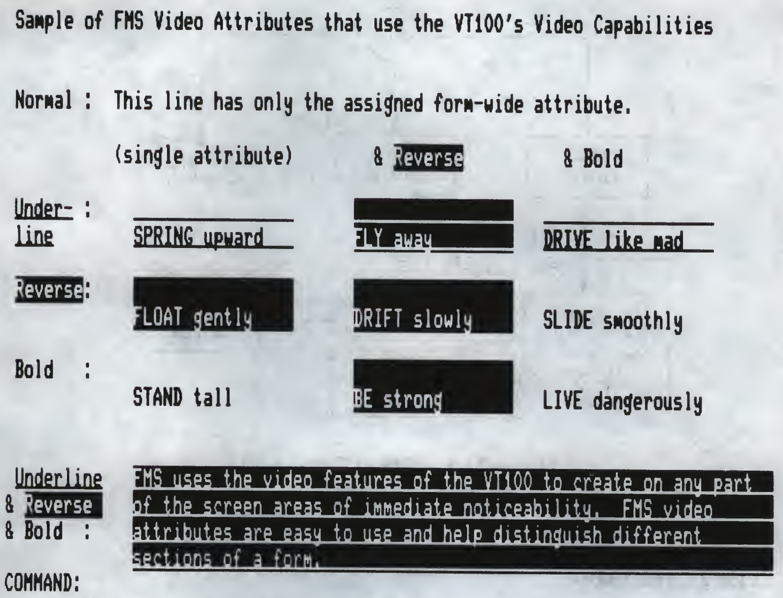


Figure 21-1 Sample Screen Form

Individual data fields can be display-only, enter-only (no echo), or restricted to modification by privileged users. Data fields can be formatted with fill characters, default values, and formatting characters (such as the dash in a phone number), which assist the user but are not visible to the application program. Fields may be right- or left-justified or may use a special fixed-decimal field type to align data properly.

Field validation includes checking each keystroke in a field for the proper data type (for example, alphabetic or numeric). Fields may also be defined as "must enter" or "must complete."

A line of information can be associated with each field, and a chain of HELP screens may be associated with each form. If users need help they press the HELP key to read a line of useful information about the current field. Subsequent key depressions yield more HELP information.

FMS-11 Programs

A number of components are used to create FMS-11 applications: the Form Editor (FED), the Form Utility (FUT), the Form Driver (FDV), and, for RT-11 only, the Application Run Time Supervisor.

Figure 21-2 illustrates the relationship of FMS-11 components to each other and to an application program.

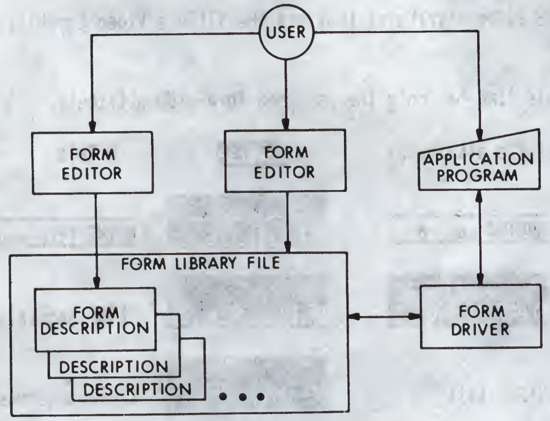


Figure 21-2 FMS-11 Components

The Form Editor

The Form Editor is a system program that provides a simple means of entering, modifying, and storing FMS-11 form descriptions. The FED lets nonprogrammers customize existing, general application programs by creating or modifying form descriptions. (This is possible because the form descriptions are independent of the applications that use them). The FED is an interactive program that uses many of the special capabilities of the VT52 and VT100 families.

When using the FED, a video screen always shows the current state of the form that is being edited. Keypad and keyboard functions allow users to specify video display characteristics for either constant text or field characters. Fields are defined on the screen with picture characters similar to those used in COBOL. Short, helpful explanations about individual fields and about each form as a whole can be included as part of the form description.

Fields and forms are accessed by name, rather than by less flexible structures such as row-column coordinates and sizes. Because the relationship between programs and fields is made at execution time, a form can be completely restructured without changing the applications that use the form.

Another feature enhancing program flexibility is *named data*. Named data provides a mechanism for storing constant data (such as file names and range check parameters) in the form description, rather than with the application program. With named data, a nonprogrammer can easily customize program parameters with the Form Editor. It allows the same application program to communicate with a form that can display information and accept input. By using named data, the programmer can write a more general, more maintainable application.

Form Utility

The Form Utility is a system program that performs a variety of form library maintenance functions, including creation of new libraries and the insertion, deletion, replacement, and extraction of individual forms. It also creates hard-copy listings of form descriptions, lists the directory of a form library, and produces object modules from form descriptions. These object modules can be linked with the application program to produce forms that are entirely memory-resident. In addition, on systems that support COBOL, the Form Utility can write out Data Division code that corresponds to a form definition and is suitable for copying into a COBOL source program.

Form Driver

The Form Driver, a reentrant system subroutine, uses the forms created with FED. Under the direction of the calling program, FDV displays forms, performs all screen management a form requires, handles all terminal I/O for application programs, and validates user responses by checking each response against the field and form descriptions. Depending on the needs of the application, programs and forms may interact on either a field-by-field or a whole record basis. The FDV may be called from applications written in any of the following languages supported by the operating system: BASIC-11, BASIC-PLUS-2, COBOL-81, FORTRAN-77, FORTRAN-IV, DIBOL-83, or MACRO-11. Because the Form Driver calls are virtually identical in all languages, proficiency in using FMS-11 is easily transferable across languages and operating systems, and programs themselves become portable.

Application Run Time Supervisor

Available only with FMS-11/RT-11, the Application Run Time Supervisor (ARTS) controls the interface between form applications and the RT-11 operating system. The ARTS runs in the background area of the RT-11 foreground/background monitor, along with the individual application programs, called tasks. When an application is running, each terminal has its own copy of a task. The ARTS includes a demand scheduler that handles resources and processing activities so that each terminal runs its task independently.

The ARTS allows multiterminal applications to be written in FORTRAN IV or MACRO-11. In multiterminal applications, concurrent tasks can share public files and resident code libraries. Applications include global system tasks not attached to any terminal. Terminal tasks use a system task by sending messages to it and receiving messages from it.

Form applications using ARTS may be either dynamic or static. Dynamic systems allow each terminal to change tasks without affecting the tasks executing at other terminals. Static systems provide fixed relationships between tasks and terminals, locking each terminal into its own individual task. Static systems are most suitable when users do the same work for long periods of time and when that work can be implemented as a small, fixed number of tasks.

Form application systems that use FDV but do not include any of the special ARTS multitask or multiterminal capabilities are also available. The most common use for such a system is debugging and testing tasks as they are being written.

The FMS-11 system generation procedure uses a clear interactive dialogue to select the ARTS features required for a particular application. The hardware on which the application executes may be predefined at ARTS generation time, or it may be specified when ARTS begins to run.

FMS-11 Example

The following code fragment (Figure 21-3) is a sample of FORTRAN application code. FMS Form Driver calls, FGET and FPFT, are used to emulate a call to get all fields, but allow the calling program to validate responses immediately on entry, before proceeding to the next field in the form.

```
        CALL FCLRSH (FORM)                ! Display the form

        CALL FGET (RESP, TERM, "*")       ! Get first field in form
        CALL FGCF (FIELD)                 ! Get the name of the field
        GOTO 2                            ! Validate response if
                                          ! necessary

1       CALL FGET (RESP, TERM, FIELD) ! Get a field

2       .
        . Validate the user's response.
        . Following validation, the variable "ERRVAL' is zero
        . if the response is valid, non-zero if invalid.
        .

        IF (ERRVAL .NE. 0) GOTO 1         ! Get field again on error
        IF (TERM .EQ. 0) GOTO 10          ! Branch if terminator was
                                          ! "ENTER'
        CALL FPFT                         ! Else process field terminator
        CALL FGCF (FIELD)                 ! Get name of field to get
        GOTO 1                            ! Get next field

10      CALL FRETAL (DATA)                ! Return responses for all
                                          ! fields
        .
        .
        .
```

Figure 21-3 Sample Code

INDENT Simplifies Your Application Program Development.

INDENT (Interactive Data Entry) is a forms management and data entry system that greatly simplifies and expedites application program development of programs written on RSTS/E systems in DIBOL, COBOL-81, or BASIC-PLUS-2. INDENT eliminates the many complexities associated with traditional forms management in commercial applications. It benefits both user and developer, allowing more efficient program development and more cost-effective application processing.

INDENT's powerful runtime system is written in reentrant, relocatable, MACRO-11 code. It controls all forms execution and communication between the application program and forms jobs running on the system. The runtime system also allows a multiterminal application to engage simultaneously in many tasks with only a single host application program.

INDENT lets you create forms, enter data through these forms, and validate data. Form definitions are created using a text editor. It supports DIGITAL's VT52 and VT100 terminals and uses the following features:

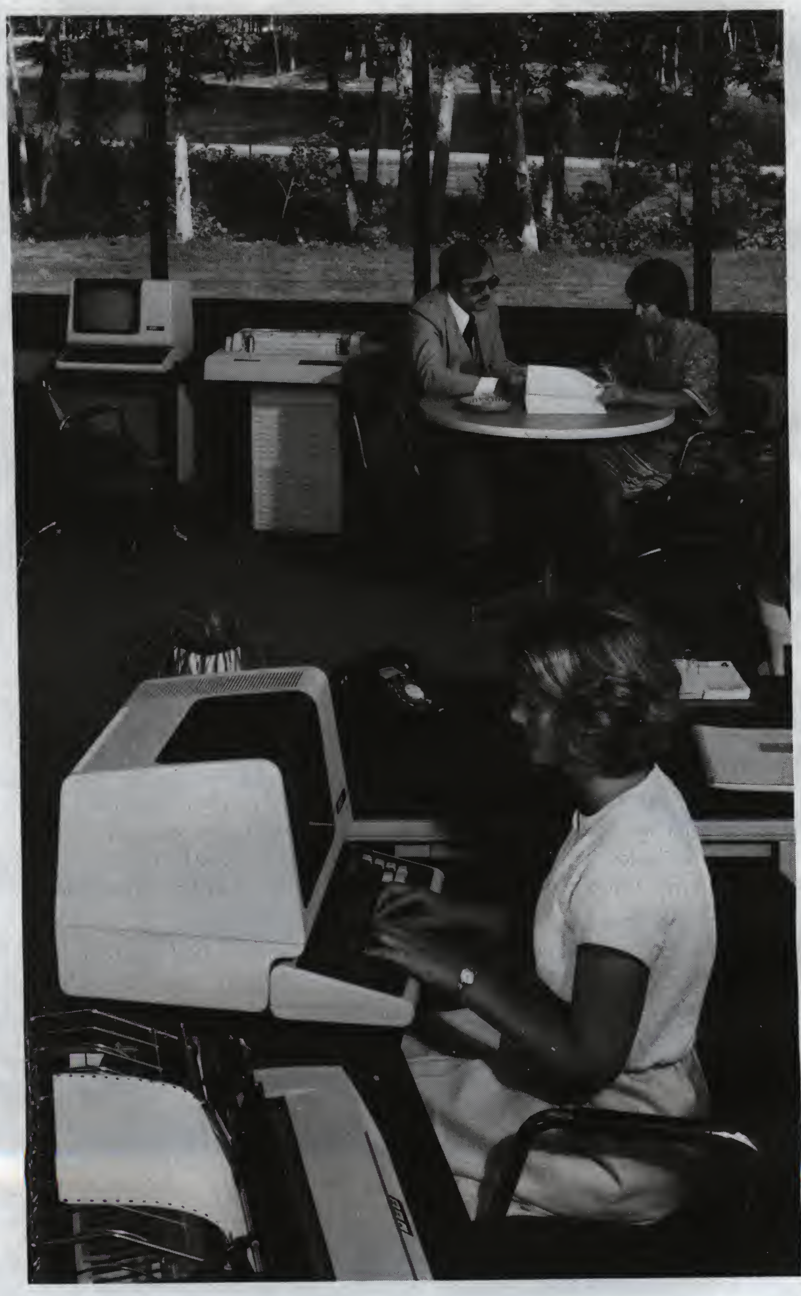
- reverse video
- bold
- underline
- blink
- 132 column lines
- scroll
- split-screen
- reverse screen
- line drawing character set

These features produce highly functional, aesthetically pleasing formats.

INDENT offers very flexible screen handling. Forms can be displayed all at once or one field at a time. Fields from different forms can be displayed one after another, while fields from a single form can be displayed in an order different from that in which they occur in the form. Forms can be chained together and portions of a form can be scrolled on the screen. Several forms can also be displayed simultaneously.

INDENT's powerful set of forms directives and host program commands offer more capabilities. Boxes and lines can be quickly defined; tables can include lists of literals or variables; form variables can be defined and accessed by host programs; forms can initialize host programs and host programs can initialize forms; defaults can be set and reset.

Application programming is simple and fast. Changes to host programs, data management, or forms definitions can be implemented independently of one another. Because the INDENT command language is so easy to use, an entry level programmer can quickly learn to create and modify forms definitions. The field definitions are simple enough so the forms designers don't have to be programmers.



Chapter 22

Distributed Processing and Networks

Networks Let Your Processors and Terminals Exchange Information.

Digital produces powerful computer hardware and software products that permit the linking of computers and terminals into flexible configurations called *networks*. With networks, you can optimize the efficiency and cost-effectiveness of your data processing operation.

No matter where your processors or terminals are located—around the plant or around the world—they can be connected in ways that allow exchange of information, files, programs, and control, as well as the sharing of peripherals. When networked, small computers can access the powerful capabilities of mainframes; large computers can take advantage of smaller dedicated systems which have been chosen for specific application environments.

With *distributed processing*, minicomputers are placed at the locations where they are needed, whether on the floor of a manufacturing plant, in an accounting department, in a laboratory, or in a home office. As organizations become more complex or develop more sophisticated demands for their computer resources, the ability to network processors and share resources becomes increasingly important. Digital has the distributed processing and networking products to provide customers with these essential capabilities.

Digital's networking architecture offers a broad range of compatible networking options.

- *DECnet* is a family of networking products which enable two or more Digital computer systems to communicate.
- Digital offers a family of protocol emulators and gateways called *Internets*. Internets provide a way for Digital computers and terminals to communicate with computers and terminals built by CDC, IBM, UNIVAC, and several other companies. Users of IBM mainframes, for example, might find it efficient to distribute a number of Digital minicomputers at various locations to do local computing, and then link them to the headquarters central computer to give management access to important information quickly and accurately.

- *Packetnets* (PSI) are computer and terminal interfaces to public packet-switched networks. These interfaces allow Digital computers to communicate with those from other manufacturers through a public data network.

Each of these series of products will be outlined in detail in this chapter. First, however, some important networking concepts will be introduced.

A *node* is a point in a network through which a user can gain access to the network or where network work can be done. In network schematics, nodes are the endpoints of the communications links that join the network. Communications links may be either dedicated, or leased, or dialed-up lines or satellite or microwave beams.

There are basically two types of nodes: routing and nonrouting. A routing node can receive messages from remote nodes and pass them to nodes other than those linked directly to itself. This sophisticated capability allows for more complex transfer of information around the network, but requires more software "overhead" to manage it. Nonrouting nodes can receive messages from anywhere in the network, but cannot pass them along. For this reason they are also sometimes referred to as "end nodes."

The phrase "point-to-point" describes the physical configuration of a network. In point-to-point networks, each node must have a physical link to any other node it wants to communicate with. Two point-to-point networks are shown below.

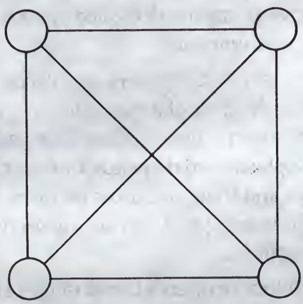


Figure 22-1 Fully Communicating Point-to-Point Network

The routing network shown in Figure 22-2 provides the same level of communication as does a fully communicating point-to-point network, but with a reduced number of lines/modems needed by using node A as a routing node.

Multidrop connections, however, are more like party telephone lines: several nodes share a single telephone line or local line. Below is an illustration of a multi-

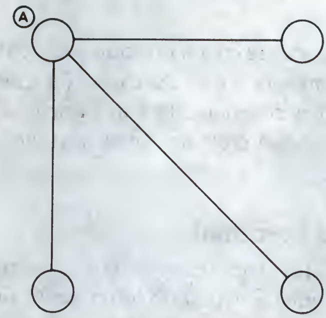


Figure 22-2 Routing Network

drop network. It is important to note that one computer is always designated as the master or control node and all other computers on that line are slaves or tributaries and respond to polling by the master node.

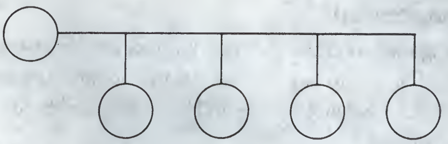


Figure 22-3 Multidrop Network

DECnet Lets Systems "Talk" to Each Other.

DECnet expands the power of Digital computers so that each system is used to its full advantage independently, and, as part of a network, is provided with additional computing benefits. There is a DECnet product to support each of Digital's major operating systems. Capabilities vary for particular DECnet systems, but generally include the following.

Adaptive Routing

Adaptive routing is the automatic routing of messages through a multisystem network. This is a technique in which the network chooses the least costly of all alternative routes for the transmission of network messages from one node to another, and automatically adjusts for faulty lines, interruptions, and changing line status. Nodes can be added or deleted without disrupting network operations. This feature makes larger networks feasible as well as cost-effective.

Multipoint

Multipoint permits nodes to share a common communication line. The tributary (or slave) nodes can only communicate with the control (or master) station when the master has polled them. They communicate with one another through the master node. It reduces communication costs by minimizing the number of lines and modems between nodes.

Network Command Terminal

This feature permits a terminal at one network node to have direct logical access to another node. The user's terminal appears to be physically linked to the other system and the standard network and system utilities of that other system are available for use. Consider, for example, a programmer in one city, say Seattle, who wants to use DATATRIEVE on a huge database stored in a computer in Boston. The Network Command Terminal feature lets that programmer work as if the Boston database were connected directly to the Seattle computer. There is no need to duplicate data and software on multiple systems. The only restriction is that the two communicating nodes be using the same operating system and DECnet software. Intermediate nodes may be any other DECnet implementation.

Network Management

Tools for monitoring and controlling network operation are the substance of network management. For day-to-day operations, the architecture includes facilities for tuning parameters, for logging events, and for testing nodes, lines, modems, and communications interfaces.

For monitoring network operation or for testing a new network application, DECnet provides statistical and error information. Statistics relate both to nodes and to communications lines, including data on traffic and error types. The network manager can get information such as the number of connect messages sent over logical links and the number received.

Line counters are also available to record statistics like the number of data blocks sent and received successfully, the number of blocks received with errors, and the number of times tributary status has changed. Data can be logged and displayed at will.

Loopback testing is a valuable aspect of network management. A network manager can send and receive test messages over individual lines, either between nodes or through other loopback arrangements, and then compare the messages. Utilities are included for a logical series of tests that aid in isolating software and hardware problems.

Access to network performance information allows potential problems to be solved before they degrade performance. If A-to-B traffic increases, the line capacity can be increased. This network management capability, combined with the per-

formance information available from the network coordinators and the Network Profile, provides unique data for planning for the future. It means people who use DECnet have control and can grow with assurance.

Task-to-Task Communication

In task-to-task communication, cooperating programs exchange data. These programs can be running under different operating systems; they can be written in different languages. One important benefit of this feature is that the network manager can make specified programs secure from access.

As an example of networked task-to-task, think of a manufacturing test/material handling application. A group of PDP-11/44s is testing system components in MACRO and FORTRAN-77 under RSX-11. Once a day, the Operations Manager reviews production schedules. The number of units that have passed final test and are ready for shipment is important information for the COBOL data analysis program running under RSTS/E at headquarters. To the failure analysis program in each RSX-11 system, the running tally it keeps of the number of units which pass the test is relatively insignificant. When the COBOL program goes to get the information for its production scheduling, though, it's there and available.

File Transfer

All DECnet systems support exchange of sequential ASCII or binary files. The DECnet software handles compatibility issues among operating systems by translating the file syntax of the sending node into a common network syntax and then retranslating at the receiving end appropriately for that node.

The transfer of file types other than sequential ASCII and binary may also be supported between particular operating systems. Check with your Digital Network Specialist for details.

As an example of file transfer, think back to the task-to-task example. Since the Operations Manager in that example needed only one record in the FORTRAN program's file, a task-to-task solution made sense. If additional information in that file had also interested the Operations Manager, transferring the whole file might have been preferable.

Remote Resource Access

Sharing such resources as expensive peripheral devices or massive database files is economical as well as convenient. A person at one node can make use of a remote disk storage device or specialized peripheral equipment that makes overhead projection transparencies from word-processor files, just as if they were nearby.

This capability is sometimes also referred to as "remote file (or record) access" when programs access file-structured devices remotely. Figure 22-4 illustrates remote resource access.

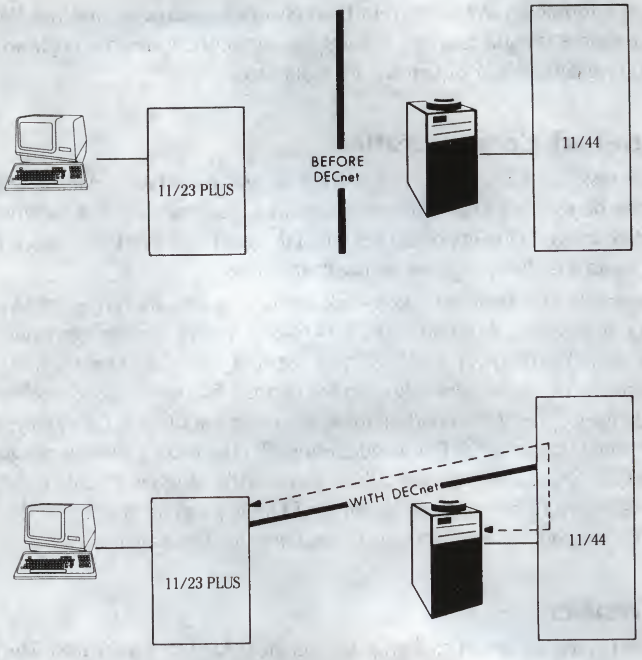


Figure 22-4 Remote Resource Access

Remote Command File Submission and Execution

A user at a source node requests a destination node to execute a command file. The command file may already be at the destination node, or the source may send it along with the request. This capability turns the user console into a remote job entry terminal for a system that supports batch or indirect command processing. In combination with the file transfer function, it's very powerful.

A small lab system, for example, might acquire data but might not be powerful enough to run the data analysis program. This could be run as a batch job on a larger processor, with the commands submitted from the lab. Later, the file containing the results could be transferred back to the lab for review.

DECnet can also support full batch capability with log file and spooling on base systems that support batch. On RSX-11M-PLUS, for example, the user can generate the node with either command file or batch capability.

Downline Loading

Tasks (programs) or whole software systems can be developed on a node with good peripheral, compiler, and memory support and then be sent to the computer where they will ultimately be used.

Downline task loading is invaluable for final check-out of application programs that have been developed by a central, but geographically separated, applications programming group.

Downline system loading (and its converse, upline system dumping) is particularly useful for small memory-based systems or for systems in hostile environments.

Our example in Figure 22-5 shows an RSX-11S system (the only system supported for downline loading) monitoring conditions in a coal mine. It is a likely candidate for downline task or system loading. New applications, once tested, can be downline task loaded. Likewise, the whole system can be regenerated and downline system loaded. The applications or system programmer can do this from a comfortable location with good computer peripheral support. Programs already executing on the core-only RSX-11S node can be checkpointed to the disk file system of an adjacent node and later restored to main memory of the RSX-11S node. No hardhat and elevator descent are required.

Upline dump of crash information is also supported for memory-only satellite nodes. The dump yields the contents of registers and memory. These may be analyzed on RSX-11M and RSX-11M-PLUS systems by a Network Crash Dump Analyzer.

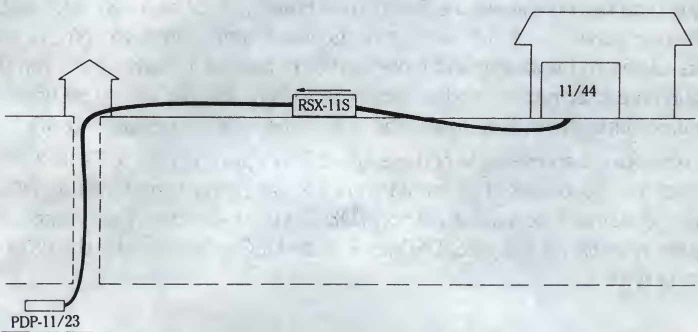


Figure 22-5 Downline Loading

Terminal Communication

The terminal communication facility has many applications. It's a handy way to talk to a person at another terminal or system console. You can request the computer operator at headquarters to mount a magnetic tape with data you need to produce a report remotely. You can tell a remote operator that you're ready to send data and that he should be prepared.

Auto-Answer

Once someone dials the number of a destination node, DECnet answers the call, which establishes the communications link, and then attends to the processing requests. Auto-Answer is supported by DECnet.

DECnet Phase IV Supports up to a Thousand Nodes.

DECnet Phase IV is Digital's latest version of network architecture. Phase IV's major enhancement is its support for Ethernet and a whole series of Ethernet products.

Ethernet is a method for handling high-speed local DECnet communications. Because of rapid advances in microprocessor technology and the widespread acceptance of personal computers, organizations that only recently evolved from centralized mainframe computing to distributed departmental computing can now justify putting a computer in every office and a terminal or personal computer on every desk. Ethernet provides a common communications path by which systems and associated terminals attached by a single connection can communicate with all other attached nodes at speeds comparable to those on the bus that links devices within a single system.

The result is a local area network that can support information exchange within, and among, all levels and departments in your organization. DECnet applications programs can be run without modification on Ethernet local area networks. A single Ethernet network can support up to a thousand nodes, although you can start with as few as you wish and add more as they're needed. Ethernet gives you the flexibility to add or remove nodes quickly and easily, without disrupting ongoing communications and without redefining or reconfiguring your entire network.

In order to get an overview of the entire DECnet picture, refer to Table 22-1. It compares the capabilities of all our different DECnet products running on PDP-11 operating systems. Note that the names of DECnet products reflect their compatible operating systems; for example, DECnet/E is the DECnet software for the RSTS/E operating system.

Internets Link Your Mainframe With Distributed Digital Systems.

Internets are a family of protocol emulator products that connect Digital computers with non-Digital systems. If you need a way for Digital computers to communicate and exchange data with computers from other manufacturers, Digital provides mechanisms for interchanging data with IBM, UNIVAC, CDC, and other host processors. Digital's goal is not to provide plug-compatible replacements for terminal subsystems, but instead, to interchange data by using common communications protocols. Emulating a protocol already recognized and supported on another vendor's system is the easiest way to speak to that system.

Table 22-1 Network Comparisons

	DECnet-11S, V3*	DECnet-RT, V2*	DECnet-11M, V4	DECnet/E, V2*	DECnet-IAS, V3*	DECnet-11M-PLUS, V4	DECnet-VAX, V3	DECnet-20, V2
NETWORK MANAGEMENT								
Loopback Testing								
Physical Link		X	X	X	X	X	X	
Logical Link	X	X	X	X	X	X	X	
Event Logging	X	X	X	X	X	X	X	
Status/Statistics								
Line	X	X	X	X	X	X	X	X
Node	X	X	X	X	X	X	X	
Node Resources	X	X	X	X	X	X	X	
Configuration	X	X	X	X	X	X	X	
Monitoring	X	X	X	X	X	X	X	
HOMOGENEOUS NETWORK								
Command Terminals	X	X[1]	X	X	X	X	X	
FILE TRANSFER								
Copy Sequential Files		X	X	X	X	X	X	X
Copy ISAM Files (Homogeneously)				X			X	X
Directory of Files		X	X	X	X	X	X	X
File Spooling			X	X	X	X		
REMOTE JOB ENTRY								
Command File Submission		X	X	X	X	X	X	
Command File Execution			X	X	X	X	X	X
Batch				X		X	X	X
REMOTE RESOURCE ACCESS								
Local Node to Remote								
Files		X	X	X	X	X	X	
Unit Record	X	X	X	X	X	X	X	
Terminal	X	X	X	X	X	X	X	
Remote Node to Local								
Files		X	X	X	X	X	X	
Unit Record	X	X	X	X	X	X	X	
Terminal	X	X	X	X	X	X	X	
LANGUAGE								
MACRO	X	X	X	X	X	X	X	X
FORTRAN IV	X	X	X	X	X	X	X	
BASIC-PLUS				X				
BASIC-PLUS-2	X		X	X	X	X		
COBOL			X	X	X		X	

*Phase III systems

Table 22-1 Network Comparisons (cont.)

	DECnet-11S, V3*	DECnet-RT, V2*	DECnet-11M, V4	DECnet/E, V2*	DECnet-IAS, V3*	DECnet-11M-PLUS, V4	DECnet-VAX, V3	DECnet-20, V2
SOFTWARE INTERFACE								
Message Level	X		X		X	X	X	X
Segment Level		X		X				
HOST SUPPORT FOR RSX-11S MEMORY-ONLY SYSTEM								
Down-Line System Load			X		X	X	X	
Down-Line Task Load			X		X	X	X	
Up-Line Crash Dump			X		X	X		
DIRECT LINE ACCESS								
MACRO	X	X	X					
Multipoint	X	X[1]	X					
Point-to-Point	X	X	X					
Multiple Lines	X		X					
TRANSPORT								
Full-Routing	X		X	X	X	X	X	
Non-Routing	X	X	X	X	X			
Point-to-Point	X	X	X	X	X	X	X	X
PHYSICAL CONNECTIONS								
Multipoint	X	X[1]	X	X		X		
Point-to-Point	X	X	X	X	X	X	X	X
Multiple Lines	X		X	X	X	X	X	X
CONFIGURATION								
Mapped, Full-Routing or Non-Routing	X	X[2]	X			X		
Unmapped, Non-Routing	X	X	X					
COMMUNICATIONS SUPPORT								
Synchronous	X	X	X	X	X	X	X	X
Asynchronous	X	X	X		X	X		
Parallel	X		X		X	X		
Local Coaxial	X	X	X	X	X	X	X	X
Local 20 mA	X	X	X		X	X		
Remote—								
EIA RS-232/CCITT (V.24)	X	X	X	X	X	X	X	X
EIA RS-449/422	X	X	X	X	X	X	X	
CCITT (V.35)	X	X	X	X		X	X	X
Half-Duplex	X	X	X	X	X	X	X	
Full-Duplex	X	X	X	X	X	X	X	X
Autoanswer	X	X	X	X	X	X	X	

* Phase III Systems.
1 Tributaries only.
2 Mapped, non-routing.

While our protocol emulator products appear to another vendor's computers to be supported devices, they are, in fact, parts of powerful Digital systems. You get local file systems, many different languages, transaction processing—a wide selection of computing power.

Internet Products Summary

Over the past several years, Digital has developed a large number of Internet products to meet customer communications needs. Our Internet products emulate these protocols:

- IBM System Network Architecture: SNA
- IBM Remote Batch: 2780, 3780, HASP Workstation
- IBM Interactive: 3271
- UNIVAC Remote Batch: UN1004
- CDC Interactive/Batch: MUX200

In addition, Digital now offers the DECnet/SNA Gateway, which links Digital and IBM *environments*, rather than merely providing single-function communications emulation between two computers. Table 22-2 below shows which members of our Internet family are supported by PDP-11 operating systems.

Table 22-2 Internet Support by Operating Systems

	2780	3780	IBM RJE/ HASP	3271	SNA	Univac UN1004	CDC MUX200
(RSX-11S)	—	—	—	—	—	—	—
RT-11 (CTS-300)	X	X		X			
RSX-11M	X	X	X	X	X	X	X
RSX-11M-PLUS	X	X	X	X			
RSTS/E (CTS-500)	X	X		X			
IAS	X		X				X

SNA

The RSX-11M/SNA Protocol Emulator provides a mechanism by which a Digital application program can exchange data with an application program in an IBM SNA network. (SNA is IBM's Systems Network Architecture.) The SNA Protocol Emulator appears to the IBM system to be a programmable cluster controller, supported by SNA. Digital realizes that many IBM users who move to SNA would like to have the flexibility of adding other vendors to the network. To meet this need, we have developed the RSX-11M/SNA Protocol Emulator.

Features

The RSX-11M/SNA Protocol Emulator (SNA P.E.) product is the link by which a Digital program exchanges data with an IBM program running in an SNA network. The Digital protocol emulator allows interactive access between a program in an IBM host and a program in a Digital system. Its application is functionally similar to that of the 3271 Protocol Emulator, except that its interface is to an SNA communications controller and driver.

The SNA P.E. appears to SNA to be a programmable cluster controller, a supported device. It supports up to four lines and up to 32 SNA sessions. It can coexist on a multipoint line with IBM SNA devices.

A particularly important feature is that it provides the flexibility of three levels of user interface. SNA is a layered architecture—different functions occupy separate layers.

Sample Application

Let's consider an example of an SNA Internet application. An automotive company has Digital equipment in five remote warehouses and a large IBM mainframe at headquarters. SNA is implemented on the IBM mainframe. Each warehouse has a PDP-11/24 running RSX-11M to maintain local inventories. The mainframe maintains the corporate database, which includes the inventories at all five warehouses.

Suppose a customer needs a part not stocked in a local warehouse. The local parts department has the opportunity to check the corporate database, by means of the SNA P. E., to see if the part is available from one of the other warehouses. The mainframe system transmits price and delivery information to the requestor. It places an order with the warehouse which has the part and updates the master and local databases. The applications themselves are handled by user-written programs. Figure 22-6 shows this SNA example.

Product Description

As stated earlier, the RSX-11M SNA P. E. is a product designed to allow RSX-11M systems to participate within an SNA environment. Since SNA is a layered architecture, each node in the network must be able to provide the layers required for SNA.

If a user wanted to use anything other than an IBM product, he would have to perform all of the functions of each SNA layer. This would be a major programming effort, requiring an indepth knowledge of SNA protocols and a commitment to provide ongoing support.

The SNA P. E. is designed to perform the functions of the SNA layers up to and including part of presentation services, depending on the level of support the user selects.

Three levels of support are available to the user:

- EC Emulator Control
- XEC Extended Emulator Control
- AC Application Control

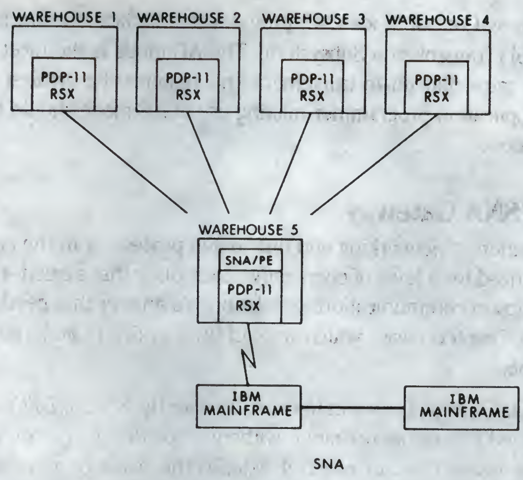


Figure 22-6 SNA Example

Regardless of the mode selected, the IBM application program and the RSX-11M application program must cooperate. This cooperation can be achieved by designing the two applications together, or by knowing the intricacies of one program and designing the other to cooperate. Simultaneous design is the preferred method, except for existing IBM applications, in which case it would probably be most practical to design the RSX-11M application to the IBM specification.

Emulator Control Mode (EC) requires the least involvement for the application in SNA protocols. EC session support is restricted to a subset of what IBM refers to as a "type 1 interactive session" of an IBM 3790 cluster controller. The application's responsibility is to identify the resource in the IBM SNA network with which it wishes to engage in a session, and to issue, send, and receive directives at the appropriate times. EC mode could be used to speak to a CICS application. The user is responsible for providing an application program (the end-user layer) in the IBM system and an application program covering the end-user level and some of the presentation services in the RSX-11M system.

Extended Emulator Control Mode (XEC) provides more support of SNA protocol but requires the user application to get more deeply involved with the SNA layers. XEC mode requires a greater knowledge of SNA protocol. The support provided is approximately the equivalent of the "type 2 interactive session" of an IBM 3790 cluster controller.

The user is responsible for providing an application program (end-user) in the IBM system and an application program in the RSX-11M system which must cover the end-user, presentation services, and part of the data flow control layers.

Applications Control Mode (AC) provides the application direct access to the SNA protocol (Transmission Subsystem). The AC mode is the most powerful, but it's also the most difficult to implement and requires the greatest programming effort. An application programmer making use of AC mode should be well-versed in SNA protocol.

DECnet/SNA Gateway

The proliferation of networking and distributed processing in the past decade has produced a need for a level of cooperative computing that exceeds the capabilities of single-function communications emulation. To answer that need, Digital developed the DECnet/Gateway, which instead links entire Digital and IBM network environments.

A DECnet/Gateway frees you to expand either the SNA or DECnet side of your total distributed processing operation without jeopardizing your present hardware and software investment. In effect, it extends the reach of a Digital network to include IBM systems connected by an SNA network. This is accomplished by combining three translator functions (remote job entry, 3270 terminal emulation, and applications program interface) and network management software into a small packaged PDP-11 front-end processor that's attached as a DECnet node.

The gateway lets you access or update an IBM mainframe database, perform remote job entry tasks, and initiate program-to-program communication. The gateway's functions are transparent to end-users, who can perform tasks from Digital workstations or VT100 terminals as if they were integral parts of an SNA network.

SNA Gateway Access is designed to make the full capabilities of SNA Data Flow Control, Transmission Control, and Path Control layers available to user programs residing anywhere in a DECnet network. SNA Gateway Access Protocol messages are exchanged over a logical link to make the facilities of SNA sessions available remotely.

SNA Gateway Access provides the following functions and features:

- Supports communication between user-written (and a number of Digital-written) programs in a host DECnet system and modules in an IBM host system over an SNA network.
- Supports programs in DECnet systems which act as Secondary Logic Units (SLUs) of any of the defined SNA Logical Unit Types (LUs).
- Allows user programs full access to the facilities provided by the SNA Transmission Control and Data Flow Control layers.
- Communicates with the SNA network as a Physical Unit Type 2 (PU2).
- Permits user-written programs to participate in SNA sessions from any DECnet system containing an SNA Gateway Access module. The user program doesn't have to reside in the DECnet system that is acting as the PU2 directly connected to the SNA network.

- Manages the SNA session pacing automatically for the user program.
- Recovers from transient errors and reports fatal errors to the user.

IBM Remote Batch Protocol Emulators (2780/3780, HASP Workstation)

Three Digital remote job entry (RJE) emulators are available for exchanging data with IBM systems: 2780, 3780 and HASP Workstation Protocol Emulators.

The Digital products offer distinct advantages over the IBM products whose protocols they emulate. At the IBM RJE stations, storage is limited to cards for input and to printer or card-punch for output from the host. The Digital Internet products, since they are integrated into base operating systems, handle all I/O through file systems. Before submitting programs, data, and commands to the host, the Digital user can create and edit files on his or her computer facilities. Output from the mainframe to the Digital system can be spooled to printer or to disk.

The 2780/3780 and HASP are the most commonly implemented communications protocols. They are excellent, low-risk, entry-level products—turnkey packages with standard IBM system software at the IBM end and a straightforward user interface at the Digital end.

In addition to IBM systems, the 2780/3780 and HASP protocol emulators can be compatible with Honeywell, Data General, and other manufacturers' products. Your Digital network specialist can help you determine how these Internets can fit into your communications design.

The IBM 2780/3780 is a card reader, card punch, printer, and control unit. It transmits a single data stream. The IBM operator loads a card deck with JCL (Job Control Language) headers and transmits the batch job. Our emulator makes use of our mass storage devices. We simulate a card deck with a JCL header in our file.

HASP is sometimes referred as "HASP Workstation" or "Multileaving Workstation." A real HASP Workstation is, functionally, an enhanced 2780. Besides the reader, punch, and printer, it supports a terminal with CRT and keyboard. Through the Digital HASP Protocol Emulator, operators can communicate directly with the IBM mainframe from a local terminal to control and check the status of jobs on the IBM host. This capability is referred to as remote console support.

The HASP Protocol Emulator product also supports multiple I/O streams, the capability of having several devices and/or file transfers active at the same time. With this multileaving capability a short job can be interleaved while a longer job is running.

IBM Programmable Interactive Protocol Emulator (3271)

Digital's 3271 Protocol Emulator provides an interactive, task-to-task link to an IBM mainframe. It provides a mechanism by which an IBM program and a Digital program can communicate.

A real 3271 (3270 is the IBM series number, 3271 the controller product) is a multidrop BISYNC cluster controller with video terminals and printers. The 3271 can transmit and receive data a screenful at a time. It is often used for form-filling applications with CICS, IMS, DL1, or user-coded applications, or for general purpose timesharing under TSO.

Our emulator appears to the IBM system as a cluster controller. To run it, you need two application programs, one for the IBM side, one for the Digital side, to send and receive the data. The IBM system treats the user application program on the Digital side as just another terminal connected to a control unit. The Digital system can coexist with 3270 terminals in a network. IBM customers can make use of their existing terminal-support application.

The Digital emulator program frames the data with appropriate characters: Start of Text, Unit Identification (Control Unit and Terminal Unit Numbers), CRCs, End Text. It segments the message into protocol-acceptable units and generally manages the line protocol as required.

The Digital user application program has two responsibilities:

- To identify itself to the protocol emulator by terminal unit and control unit number. This step is also referred to as "attaching a pseudodevice."
- To send/receive data in a format acceptable to the IBM program at the other end.

Note also that, since the 3271 Protocol Emulator emulates a cluster controller, multiple Digital user application programs can send/receive data simultaneously to/from the mainframe on the same physical line. The 3271 also provides multiline support.

UNIVAC Protocol Emulators (UN1004)

UN1004/RSX is a PDP-11-based software package that provides a means of communication with UNIVAC 1100 series mainframes. This product can be compared functionally to the IBM 2780 protocol emulator. The 2780 protocol is symmetrical, but the UN1004 protocol allows only specific nonidentical operations by each of the communicating components. In simple language, this means that while the 2780 protocol could, in principle, be used to communicate between two PDP-11s, the UN1004 could not.

The UN1004 protocol was designed by UNIVAC to provide communication between a host UNIVAC 1100 series mainframe and a remote batch terminal consisting of a keyboard, a card reader/punch, and a lineprinter. The input for UN1004/RSX can be from any valid RSX-11M-supported peripheral that will store a valid UNIVAC batch stream.

Although the UN1004/RSX emulator is a single-user product, more than one user can submit jobs to a common job queue. The resulting output from the UNIVAC host will be received in a common queue which does not contain any user identification.

Figure 22-7 illustrates a typical UN1004 configuration.

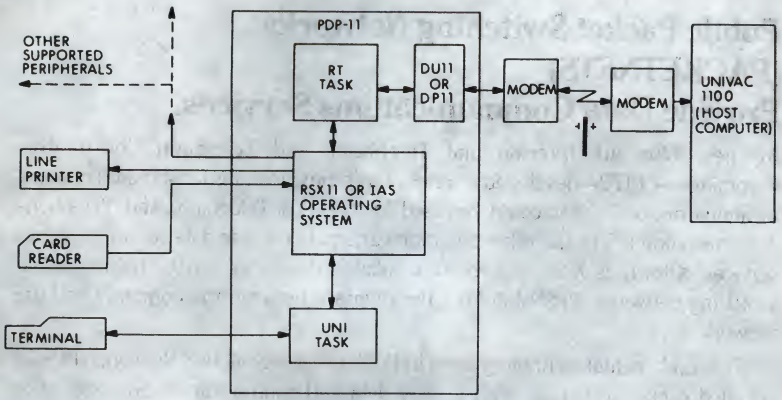


Figure 22-7 UN1004 Configuration

CDC Protocol Emulator (MUX200)

MUX200/RSX-IAS is a PDP-11-based software package that provides a means of communicating with a CDC-6000 or CDC-CYBER series host computer. The product may be used to communicate to the host computer either interactively or in remote job entry (RJE) mode. Up to 16 terminals may be connected to the host through MUX200/RSX. However, in many cases the host software restricts this number to 12. Each of the interactive users may submit jobs to a job queue that MUX200/RSX-IAS uses to schedule transmissions to the host. Output from the host is automatically spooled to a device which has been defined by the system manager.

The protocol used is the CDC mode 4A protocol, which allows speeds up to 9600 baud. Note that the Digital product is warranted for speeds up to 4800 baud.

MUX200/RSX-IAS is not a one-to-one replacement for the CDC-200UT, which uses the same protocol.

MUX200/RSX-IAS has the following features:

- Output received from the host CDC system may be spooled to a lineprinter upon detection of a text string predefined by the user.
- Up to eight RSX-IAS datasets may be specified for transmission to the host in a single command.
- RSX-IAS terminals may be detached for other use while the software package is operating. Data received from the host that are directed to the terminal are saved for printout when the terminal is reattached.
- User-written tasks can replace the RSX-IAS terminal and control the emulator as if the task were a terminal.

Public Packet Switching Networks (PACKETNETS) Provide Data Communications Services.

In the 1970s the International Telephone and Telegraph Consultative Committee—CCITT—developed a series of recommendations for standard communications protocols that could be used by the Post,Telegraph, and Telephone Administration (PTT) and other common carriers to provide data communications services. Known as X.25, this recommendation developed for the public packet-switching networks (PPSNs) defines the interface between the computer and the network.

The fundamental technology used in Public Packet-Switched Networks (PPSNs) is called packet switching. With it, user data and control information needed to assure delivery to the correct location are formed into discrete entities—packets. The network dynamically interleaves the packets of many users over shared transmission facilities, and routes packets to their destinations. Unlike conventional telephone setups, where the user is charged for both connect time and distance, regardless of the amount of data passed, charges in PPSNs are determined so that the person who uses the line the most pays the most.

Digital's Implementation of the X.25 Interface

Since 1975, Digital has been following the growth of packet-switched networks with great interest and has an ongoing program to provide the X.25 software on its 16—, 32—, and 36-bit computer systems. The X.25 interface has been incorporated into Digital Network Architecture so that Digital-based networks can communicate over both a nationwide PPSN and a private network at the same time. No other computer manufacturer supports this type of approach to networking, under multiple computer architectures and operating systems.

X.25 is rapidly becoming the standard international communications protocol, as it finds increasing acceptance among users and computer manufacturers. X.25 allows computers from different manufacturers to work together: with appropriate security validation, any system on the network can send data to any other system on the network. X.25 provides dynamic routing and ensures data integrity, at the same time relieving users of any concern about input and output speeds of the various processors in the network.

Before the advent of packet-switched networks, users required leased or switched lines. These lines are generally not used very efficiently since there are long idle periods between actual data transmissions. Sending data in packets significantly improves the efficiency of the transmission lines, since, by sharing the line among many users, the amount of time the line is idle is reduced. Bandwidth is allocated only when a user is actually transmitting data.

Within the near future, interfaces to PPSNs will be available in:

- United States—Telenet
- United States—Tymnet
- Canada—Datapac
- France—Transpac
- United Kingdom—PSS
- Holland—DN1
- Germany—Datex-P
- Switzerland—Telepac

As others become operational, they will be selectively supported.

Appendix A

DECUS

DECUS (The Digital Equipment Computer Users Society), a worldwide association of customers and employees, provides a forum for the exchange of useful information, new program packages, and other innovations among those who use and supply Digital products.

DECUS membership is free—upon application—to owners of Digital computers and to their computer-interested employees. Membership carries important benefits and opportunities; among these are access to the program library; membership in local, regional, and national organizations; invitations to symposia dedicated to optimal use of Digital equipment; opportunity to present papers and workshops on your own ideas; and, finally, access to special interest groups dedicated to particular uses, languages, operating systems, and hardware configurations.

The program library maintained by DECUS contains over 1500 active software packages written and submitted by members and Digital employees, and available to you for the media fee and reproduction cost only. Programs in the library range from enhanced editors and cross-compilers to statistics packages and games. Of particular interest to college and university customers, for example, might be a package of programs for registration, class scheduling, dormitory management, and annual giving records. A laboratory user could take advantage of various statistical packages or programs that perform Fourier transforms or least squares fitting. There are programs for circuit analysis, resonance simulation, blood-count evaluation, and stress testing, and scores of others that medical, scientific, or engineering customers could use. Business people can find accounting packages, case studies, and payroll programs amoung the library's offerings. In addition, of course, there is a wide range of data management, display graphics, and enhanced utility programs available.

Local, regional, and national DECUS organizations give members the opportunity to meet other Digital customers and employees in an informal setting. From the monthly local meeting to the semiannual national symposium, the members can discuss their ideas, can learn what others are doing, and can give Digital feedback necessary for improvement and future development of important products. Often, the national meetings in the various countries also provide the stage for major new product announcements by the company and a showplace for interesting developments in both hardware and software technology. At any meeting members might describe ideas and programs they have implemented, or fine-tuning that has been achieved for a particular application. Members give papers, participate in panel discussions, lead workshops, or conduct demonstrations for the benefit of other members.

DECUS also publishes newsletters focusing on special interests, technical books that contain the compilation of symposia presentations, and a society newsletter.

Many members derive a particular benefit from joining DECUS Special Interest Groups. Special Interest Groups often meet as subsets of regional and national meetings, or they may meet on their own, to discuss their special field. Here, for example, all RSTS/E users or everyone interested in COBOL can have a chance to get together and discuss topics of mutual interest. At present there are at least 25 Special Interest Groups (SIGs) in the US alone. Many of the SIGs print newsletters and disseminate valuable technical information to members. The SIGs really are the front-line of mutual help and problem solving.

Digital provides DECUS with administrative personnel and office space around the world, but the organization is run by its members, who act as speakers for conferences, planners for meeting, editorial and production talent for newsletters and minutes, and the inventors of the ideas and new programs necessary to keep the library up to date. Belonging to DECUS is a valuable adjunct to owning Digital equipment on both the program exchange and the information exchange fronts.

For further information about DECUS, contact:

DECUS
(MRO2-1/C11)
One Iron Way
Marlboro
MA 01752

Appendix B
PDP-11 Software Sourcebook

PDP-11 computers are the most popular micro and minicomputer family of all time. That popularity is reflected in the fact that the PDP-11 has the greatest number of proven applications available to any micro or mini family in the industry. The First Edition of *The PDP-11 Software Sourcebook* is over 900 pages long and covers a collection of over 1200 of these application packages— not software under development, but software that is available now and already at work in businesses and organizations.

Applications mentioned include those sold by Digital, products available through DECUS, and programs in the External Software Applications Library (EAS)— applications written by independent vendors but tested by Digital to verify that they can be installed in the manner described and that they perform in accordance with their documentation.

There are five "roadmaps" (cross-reference systems) into the book to help you find particular applications:

- The Contents lists the industries and generic disciplines covered in the book.
- The Keyword Cross-Reference Guide classifies the software packages by keyword (such as "Acoustics" or "Electronic Mail").
- The Operating System Cross-Reference Guide lists the software packages by operating system.
- The Alphabetical Entry Listing gives the title and page number of each program in the book.
- The Index provides a detailed alphabetical listing by subject.

The PDP-11 Software Sourcebook can be ordered by writing to:

ATTN: G. Deforge
DIGITAL EQUIPMENT CORPORATION
Printing and Circulation Services
444 Whitney Street
Northboro, Massachusetts 01532

Ask for Order Code: ED-24762-20

Appendix C

Commonly Used Abbreviations

A	Amperes
A/D	Analog/digital
ACP	Ancillary Control Processor
ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
AST	Asynchronous System Trap
ATL	Active Task List
BAC	BASIC Compiled Program File
BAK	Back-up file
BAS	BASIC source program file
BASIC	Beginner's All-purpose Symbolic Instruction Code
BAT	Batch file
BI	Batch input device
BP	Batch pseudo-device
CAI	Computer Assisted Instruction
CBL	COBOL source program
CCITT	International Telephone and Telegraph Consultative Committee
CIL	Core Image Library
CL	Console Log device
CLI	Command Language Interpreter
CMD	Command file
CMI	Computer Managed Instruction
CO	Console Output device
COB	COBOL source program
COBOL	Common Business Oriented Language
COMTEX	Communications Oriented Multiple Terminal Executive

Commonly Used Abbreviations

CPU	Central Processing Unit
CR	Card Reader
CRC	Cyclic Redundancy Check
CREF	Cross-Reference
CRT	Cathode Ray Tube
CSECT	Control Section
CSI	Command String Interpreter
CT	Cassette Tape
CTRL	Control key
CUSPs	Commonly-Used System Programs
DAT	Data file
DBMS	Data Base Management System
DEC	Digital Equipment Corporation
DDCMP	Digital Data Communications Message Protocol
DIR	Directory File
DMP	Dump File
DMS	Data Management System
DNA	Digital Network Architecture
DOS	Disk Operating System
DP	Data Processing
DPB	Directive Parameter Block
DSM	Digital Standard Mumps
DSW	Directive Status Word
DT	DECtape
EAE	Extended Arithmetic Element
EDT	Digital standard editor
EDI	Editor utility
EDIT	Editor utility
EIA	Electronics Industry Association
EIS	Extended Instruction Set
EMT	Emulator Trap
EOD	End of Data
EOF	End of File
EOJ	End of Job

EOL	End of Line
EOM	End of Medium
FA	Formatted ASCII
FB	Formatted Binary
F/B	Foreground/Background
FCP	File Control Primitives
FCS	File Control Services
FDB	File Data Block
FILEX	File Exchange utility
FIS	Floating Instruction Set
FLX	File Exchange utility
FNB	Filename Block
FOR	FORTRAN source program
FORTRAN	Formula Translator
FPP	Floating Point Processor
FSR	File Storage Region
FTN	FORTRAN source program
F4P	FORTRAN IV-PLUS source program
G	Giga (one billion)
GT	Graphics Terminal
HASP	Houston Automatic Spooling Program
Hz	Hertz
IAS	Interactive Application System
ID	Identification code
I/O	Input/Output
IOT	Input/Output Trap
IOX	I/O Executive
ISR	Interrupt Service Routine
JMP	Jump
JSR	Jump to Subroutine
K	1024 decimal (2^{10})
KB	Keyboard
KBL	Keyboard Listener
KCT	Kilo-Core Tick
LBR	Librarian

LDA	Load module
LED	Light Emitting Diode
LIB	Library file
LIBR	Librarian
LICIL	Linked Core Image Library
LIS	Listing file
LP	Line printer
LST	Listing file
LUN	Logical Unit Number
μ	micro (mu— one millionth)
m	milli (one thousandth), or meters
M	mega (1024^2)
MAC	MACRO source program
MAP	Load map
MCR	Monitor Console Routine
MFD	Master File Directory
MO	Message Output device
MST	Macro Symbol Table
MT	Magnetic Tape
MTBF	Mean Time Between Failures
n	nano (one billionth)
NCP	Network Control Processor
NPR	Nonprocessor Request
OBJ	Object Module
ODL	Overlay Description Language
ODT	Online Debugging Technique
OEM	Original Equipment Manufacturer
OTL	Online Task Loader
OTS	Object Time System
PC	Program Counter
PDF	Processor-Defined Function
PDS	Program Development System
PDP	Programmed Data Processor
PIC	Position Independent Code

PIP	Peripheral Interchange Program
PP	Papertape Punch
PR	Papertape Reader
PSECT	Program Section
PST	Permanent Symbol Table
PTT	Post, Telegraph, and Telephone Administration
PUD	Physical Unit Directory
QIO	Queue I/O
ROM	Read-only Memory
RSTS/E	Resource-sharing Timesharing System/Extended
RSX-11	Realtime Resource Sharing Executive
RT-11	Realtime Foreground/Background System
RTS	Run Time System
RWED	Read, Write, Extend, and Delete
SAV	Saved File or System Image File
SCI	System Control Interface
SCOM	System Communication Area
SGA	Sharable Global Area
SIP	System Image Preservation
SIPP	Save Image Patch Program
SP	Stack Pointer
SPC	Small Peripheral Controller
SPR	Software Performance Report
SST	Synchronous System Trap
SY	System device
SYS	System file
SYSGEN	System Generation
TCP	Timesharing Control Primitives
TI	Terminal Interface
TKB	Task builder
TKTN	Task Termination Notice
TMP	Temporary file
TSK	Task Image File
TT	Terminal device

TTY	Terminal Device
UA	Unformatted ASCII
UB	Unformatted Binary
UFD	User File Directory
UIC	User Identification Code
USR	User Service Routine
UST	User Symbol Table
V	Volts
VDT	Video Display Terminal
VT50	DECscope video display terminal
VT52	Table-top alphanumeric video display terminal
VT100	High-performance video terminal
XOR	Exclusive OR

Appendix D

ASCII Codes

Control Characters

CHAR	OCTAL	BINARY
NUL	000	0000000
SOH	001	0000001
STX	002	0000010
ETX	003	0000011
EOT	004	0000100
ENQ	005	0000101
ACK	006	0000110
BEL	007	0000111
BS	010	0001000
HT	011	0001001
LF	012	0001010
VT	013	0001011
FF	014	0001100
CR	015	0001101
SO	016	0001110
SI	017	0001111
DLE	020	0010000
DC1	021	0010001
DC2	022	0010010
DC3	023	0010011
DC4	024	0010100
NAK	025	0010101
SYN	026	0010110
ETB	027	0010111
CAN	030	0011000
EM	031	0011001
SUB	032	0011010
ESC	033	0011011
FS	034	0011100
GS	035	0011101
RS	036	0011110
US	037	0011111
DEL	177	1111111

Control Character Key

NUL = All zeros
SOH = Start of heading
STX = Start of text
ETX = End of text
EOT = End of transmission
ENQ = Enquiry
ACK = Acknowledgement
BEL = Bell or attention signal
BS = Back space
HT = Horizontal tabulation
LF = Line feed
VT = Vertical tabulation
FF = Form Feed
CR = Carriage return
SO = Shift out
SI = Shift in
DLE = Data link escape
DC 1 = Device control 1
DC 2 = Device control 2
DC 3 = Device control 3
DC 4 = Device control 4
NAK = Negative acknowledgement
SYN = Synchronous/idle
ETB = End of transmitted block
CAN = Cancel (error in data)
EM = End of medium
SUB = Start of special sequence
ESC = Escape
FS = Information file separator
GS = Information group separator
RS = Information record separator
US = Information unit separator
DEL = Delete

Printable Characters

CHAR	OCTAL	BINARY
SP	040	0100000
!	041	0100001
"	042	0100010
#	043	0100011
$	044	0100100
%	045	0100101
&	046	0100110
'	047	0100111
(	050	0101000
)	051	0101001
*	052	0101010
+	053	0101011
,	054	0101100
-	055	0101101
.	056	0101110
/	057	0101111
0	060	0110000
1	061	0110001
2	062	0110010
3	063	0110011
4	064	0110100
5	065	0110101
6	066	0110110
7	067	0110111
8	070	0111000
9	071	0111001
:	072	0111010
;	073	0111011
<	074	0111100
=	075	0111101
>	076	0111110
?	077	0111111
@	100	1000000

Printable Characters

CHAR	OCTAL	BINARY
A	101	1000001
B	102	1000010
C	103	1000011
D	104	1000100
E	105	1000101
F	106	1000110
G	107	1000111
H	110	1001000
I	111	1001001
J	112	1001010
K	113	1001011
L	114	1001100
M	115	1001101
N	116	1001110
O	117	1001111
P	120	1010000
Q	121	1010001
R	122	1010010
S	123	1010011
T	124	1010100
U	125	1010101
V	126	1010110
W	127	1010111
X	130	1011000
Y	131	1011001
Z	132	1011010

Printable Characters

CHAR	OCTAL	BINARY
a	141	1100001
b	142	1100010
c	143	1100011
d	144	1100100
e	145	1100101
f	146	1100110
g	147	1100111
h	150	1101000
i	151	1101001
j	152	1101010
k	153	1101011
l	154	1101100
m	155	1101101
n	156	1101110
o	157	1101111
p	160	1110000
q	161	1110001
r	162	1110010
s	163	1110011
t	164	1110100
u	165	1110101
v	166	1110110
w	167	1110111
x	170	1111000
y	171	1111001
z	172	1111010

GLOSSARY

absolute address A binary number that is assigned as the address of a physical memory storage location.

absolute loader A stand-alone program which, when in memory, enables the user to load into memory data in absolute binary format.

access privileges Attributes of a file which specify the class of users allowed to access the file.

account number A discrete code used to identify a system user. It normally consists of two numbers, separated by a comma, called the project number and programmer number or the group number and member number. See also *user identification code.*

active task list A priority-ordered list of active tasks used normally in an event-driven multiprogrammed system to determine the order in which tasks receive control of the CPU.

address 1. A name, label, or number which identifies a register, a location in storage, or any other data source or destination.
2. The part of an instruction that specifies the location of an operand of that instruction.

adjacent node A node removed from the local node by a single physical line.

algorithm A prescribed set of well-defined rules or processes for the solution of a problem; a program.

alphanumeric Referring either to the entire set of 128 ASCII characters or the subset of ASCII characters which includes the 26 alphabetic characters and the ten numeric characters.

ancillary peripherals In the DSM-11 system, peripherals not under control of the data base supervisor.

ANSI American National Standards Institute.

append To add information to the end of an existing file.

application program A program that performs a task for a particular end-user's needs. Generally, an application program is any program written on a program development operating system that is not part of the basic operating system.

argument 1. A variable or constant which is given in the call of a subroutine as information to it.
2. A variable upon whose value the value of a function or other operation depends.
3. The known reference factor necessary to find an item in a table or array (i.e., the index).

array An ordered arrangement of subscripted variables.

ASCII The American Standard Code for Information Interchange, consisting of 128 7-bit binary codes for upper and lower case letters, numbers, punctuation, and special communication control characters.

assemble To translate from a symbolic program to a binary program by substituting binary operation codes for symbolic operation codes and absolute or relocatable codes and absolute or relocatable addresses for symbolic addresses.

assembler A program that translates symbolic source code ("assembly level language") into machine instructions by replacing symbolic operation codes with binary operation codes and symbolic addresses with absolute or relocatable addresses.

assembler directives The mnemonics used in an assembly language source program that are recognized by the assembler as commands to control and direct the assembly process.

assembly language A symbolic programming language that can normally be translated directly into machine language instructions and is, therefore, specific to a given computing system.

assembly listing A listing produced by an assembler that shows the symbolic code written by a programmer next to a representation of the actual machine instructions generated.

assigning a device Putting an I/O device under control of a particular user's job either for the duration of the job or until the user relinquishes control. See also *attach.*

asynchronous A mode of operation in which an operation is started by a signal that the operation on which it depends is completed. When referring to hardware devices, it is the method in which each character is sent with its own synchronizing information. The hardware operations are scheduled by ready and done signals rather than by time intervals. In addition, it implies that a second operation can begin before the first operation is completed.

asynchronous system trap A system condition which occurs as the result of an external event such as completion of an I/O request. On occurrence of the significant event, control passes to an AST service routine.

asynchronous transmission Time intervals between transmitted characters may be of unequal length. Transmission is controlled by start and stop elements at the beginning and end of each character. Also called Start-Stop transmission.

attach To dedicate a physical device unit for exclusive use by the task requesting attachment. See also *assigning a device.*

background processing The automatic execution of a low priority computer program when higher priority programs are not using the system resources.

backup file A copy of a file created for protection in case the primary file is unintentionally destroyed.

bad block A defective block on a storage medium that produces a hardware error when attempting to read or write data in that block.

base address An address used as the basis for computing the value of some other relative address.

base segment The always-memory-resident portion of a program that uses overlays. See also *root segment*.

batch processing A method of scheduling programs in which programs are accumulated and fed to the computer for execution with no programmer interaction.

batch stream The collection of commands and data interpreted by a batch processor that directs batch processing.

baud 1. A unit of signalling speed equal to the number of signal events per second.
2. For asynchronous transmissions, the unit of modulation rate corresponding to one unit interval per second. If, for example, the length of the unit's interval is 25 milliseconds, the modulation rate is 40 baud. Baud is frequently, though erroneously, used as a synonym for bits per second.

binary The number system with a radix of two.

binary code A code that uses two distinct characters, usually the numbers 0 and 1.

binary loader See *absolute loader.*

bit A binary digit.

bit map A table describing the state of each member of a related set. A bit map is most often used to describe the allocation of storage space. Each bit in the table indicates whether a particular block in the storage medium is occupied or free.

block 1. A group of specified size of physically adjacent words or bytes. A block size is particular to a device.
2. The smallest system-addressable segment on a mass-storage device in reference to I/O.

Boolean valued expression An expression which, when evaluated, produces either "true" or "false" as a result.

bootstrap 1. A technique or device designed to bring itself into a desired state by its own action.
2. To cause an operating system to load itself and prepare to run.

bootstrap loader A routine whose first instructions are sufficient to load the remainder of itself into memory from an input device and normally start a complex system of programs.

bottom address The lowest memory address in which a program is loaded.

bps Bits per second. A commonly used measure for data transfer rate. (Other notations are bit, b.p.s., bit/sec, etc.)

breakpoint A location at which program operation is suspended in order to examine partial results. A preset point in a program where control passes to a debugging routine.

buffer A storage area used to temporarily hold information being transferred between two devices or between a device and memory. A buffer is often a special register or a designated area of memory.

bug An instruction or sequence of instructions in a program that causes unexpected and undesired results.

bus One or more conductors used for transmitting signals or power from one or more sources to one or more destinations, but usually with many connections.

byte The smallest memory-addressable unit of information in a PDP-11 system. A byte is equivalent to eight bits.

call To transfer control to a specified routine.

calling sequence A specified arrangement of instructions and data necessary to pass parameters and control to a given subroutine.

carriage return key The key on a terminal keyboard most often used in PDP-11 systems to terminate input lines.

CCITT Comittee Consultatif Internationale Telegraphie et Telephonie, a committee which sets international communications standards.

Central Processing Unit (CPU) or Central Processor That part of a computing system containing the arithmetic and logical units, instruction control unit, timing generators, and memory and I/O interfaces.

character A single letter, numeral, or symbol used to represent information.

checkpoint A point in a program or routine at which job and system status are recorded, so that the job can later be restarted.

checksum A number used for checking the validity of data transfers.

clear 1. To erase the contents of a storage location by replacing the contents with zeros or spaces.
2. In binary code, to set to zero.

clock A time-keeping or frequency-measuring device within a computing system.

code A system of symbols and rules used for representing information.

coding Writing instructions for a computer using symbols meaningful to the computer itself, or to an assember, compiler, or other language processor.

collate To combine items from two or more ordered sets into one set having an order not necessarily the same as any of the original sets.

command or command name A word, mnemonic, or character which, by virtue of its syntax in a line of input, causes a predefined operation to be performed by a computer system.

command language The vocabulary used by a program or set of programs that directs the computer system to perform predefined operations.

Command Language Interpreter The program that translates a predefined set of commands into instructions that a computer system can interpret.

command string A line of input to a computer system that generally includes a command, one or more file specifications, and optional qualifiers.

Command String Interpreter A special program or routine that accepts a line of ASCII string input and interprets the string as input and output file specifications with recognized qualifiers.

common A section in memory which is set aside for common use by many separate programs or modules.

compatibility The ability of an instruction, source language, or peripheral device to be used on more than one computer.

compile To translate a source (symbolic) program into a binary-coded program. In addition to translating the source language, appropriate subroutines may be selected from a subroutine library. Linkage is supplied, and everything is output in binary code along with the main program.

compiler A program which translates a higher level source language into a language suitable for a particular machine.

completion routine A routine that is called at the completion of an operation.

compute bound A state of program execution in which all operations are dependent on the activity of the central processor, for example, when a large number of calculations is being performed. Contrast with *I/O bound.*

computer operator A person who performs standard system operations such as adjusting system operation parameters at the system console, loading a tape transport, placing cards in a card reader, and removing listings from the line printer.

concatenate To combine several files into one file, or several strings of characters into one string, by appending each file or string one after the other.

conditional assembly The assembly of parts of a symbolic program only when certain conditions are met.

configuration A particular selection of hardware devices or software routines or programs that function together.

consecutive access The method of data access characterized by the sequential nature of the I/O device involved. For example, a card reader is an example of a consecutive access device. Each card must be read after the preceding one, and no distinction is made between logical sets of data in or among the cards in the input hopper.

console The console of a central processor is the set of switches and display lights used by an operator or programmer to determine the status and control the operation of the computer.

console terminal A keyboard terminal which acts as the primary interface between the computer operator and the computer system and is used to initiate and direct overall system operation through software running on the computer.

constant A value which remains the same throughout a distinct operation. Compare with *variable*.

context switching The switching between one mode of execution and other, involving the saving of key registers and other memory areas prior to switching between jobs, and restoring them when switching back. A common example of context switching is the temporary suspension of a user program so that the monitor or executive can execute an operation.

contiguous file A file consisting of physically adjacent blocks on a mass-storage device.

control character A character whose purpose is to control an action rather than to pass data to a program. An ASCII control character has an octal code between 0 and 37. It is typed by holding down the CTRL key on a terminal keyboard while striking a character key.

control section A named, contiguous unit of code (instructions or data) that is considered an entity and that can be relocated separately without destroying the logic of the program.

core memory The most common form of main memory storage used by the central processing unit, in which binary data are represented by the switching polarity of magnetic cores.

core common See *common*.

crash A hardware crash is the complete failure of a particular device, sometimes affecting the operation of an entire computer system. A software crash is the complete failure of an operating system characterized by some failure in the system's protection mechanisms.

create To open, write data to, and close a file for the first time.

cross reference listing or table A printed listing that identifies all references in a program to each specific label in a program. A list of all or a subset of symbols used in a source program and statements where they are defined or used.

CTRL/C (C) The control character issued from a terminal which is most commonly used to return the operator to communication with the system-level program. In most PDP-11 systems, it is typed on the terminal keyboard to gain the attention of the operating system before commencing the login procedure, or to terminate the currently executing program and return to communication with the monitor. In some cases, it simply issues a call to the console listener or console service routine without interrupting current program execution.

CTRL/U (U) The control character issued from a terminal that tells the program currently accepting input to ignore the characters entered on the line up to the point where CTRL/U was typed.

CTRL/Z (Z) The control character used in RSX-11 systems to terminate the system program currently waiting for input from the terminal. It is essentially an end-of-file character.

data base A collection of interrelated data items organized by a consistent scheme that allows one or more applications to process the items without regard to physical storage locations.

data base management system A scheme used to create, maintain, and reference a data base.

debug To detect, locate, and correct coding or logic errors in a computer program.

DECnet A family of hardware/software products that create distributed networks from DIGITAL computers and their interconnecting data links.

DECtape A convenient, pocket-sized reel of magnetic tape developed by DIGITAL for extremely reliable data storage and random access.

default The value of an argument, operand, or field assumed by a program if a specific assignment is not supplied by the user.

delimiter A character that separates, terminates, or organizes elements of a character string, statement, or program.

detach a device Free an attached physical device unit for use by tasks other than the one that attached it.

device A hardware unit such as an I/O peripheral, e.g., magnetic tape drive or card reader. Also often used synonymously with volume.

device controller A hardware unit which electronically supervises one or more of the same type of devices. It acts as the link between the CPU and the I/O devices.

device driver A program that controls the physical hardware activities on a peripheral device. The device driver is generally the device-dependent interface between a device and the common, device-independent I/O code in an operating system.

device handler A program that drives or services an I/O device. A device handler is similar to a device driver, but provides more control and interfacing functions than a device driver.

device independence The ability to request I/O operations without regard for the characteristics of specific types of I/O devices.

device name A unique name that identifies each device unit on a system. It usually consists of a 2-character device mnemonic followed by an optional device unit number and a colon. For example, the common device name for DECtape drive unit one is "DT1:"

device unit One of a set of similar peripheral devices; e.g., disk unit 0, DECtape unit 1. Also used synonymously with *volume.*

diagnostic Pertaining to the detection and isolation of malfunctions or mistakes.

dial-up line A communications circuit that is established by a switched circuit connection.

DIGITAL Network Architecture (DNA) The common network architecture of DECnet.

digital transmission Transmission of data characters which are coded into discrete separate pulses or signal levels.

direct access See *random access*.

direct mode The mode of DSM-11 system operation which enables the programmer to enter commands and or functions for immediate execution, and to create or modify steps of a user's program.

directive A type of executive request issued by a program that provides a facility inherent in the hardware which is controlled and organized by the operating system. See also *programmed request*.

directory A table that contains the names of and pointers to files on a mass-storage device.

directory device A mass-storage retrieval device, such as disk or DECtape, that contains a directory of the files stored on the device.

disk 1. A mass storage device. Basic unit is an electromagnetic platter on which data are magnetically recorded. Features random access and faster access time than magnetic tape.
2. The platter itself.

double-buffered I/O An input or output operation which uses two buffers to transfer data. While one buffer is being used by the program, the other buffer is being read from or written to by an I/O device.

down-line load The process by which one node in a computer network transfers an entire system image or a program (task) image to another node and causes it to be executed.

dump To copy the contents of all or part of core memory, usually onto an external storage medium. Also, the copy so produced.

EBCDIC Extended Binary Coded Decimal Interchange Code. A binary code used on the IBM System/360 and System/370 as well as other manufacturers' systems that have a need to be compatible with IBM.

echo The printing by an I/O device, such as teletype or CRT, of characters typed by the programmer.

editor A program which interacts with the programmer to enter new programs into the computer and edit them as well as modify existing programs. Editors are language-independent and will edit anything in alphanumeric representation.

emulator A hardware device that permits a program written for a specific computer to be run on a different type of computer system.

executive The controlling program or set of routines in an operating system. The executive coordinates all activities in the system including I/O supervision, resource allocation, program execution, and operator communication. See also *monitor*.

executive mode A central processor mode characterized by the lack of memory protection and relocation by the normal execution of all defined instruction codes.

exponentiation A mathematical operation denoting increases in the base number by a factor previously selected.

expression A combination of operands and operators which can be evaluated by a computing system.

external storage A storage medium other than main memory, for example, paper tape, magnetic tape, or disks.

field 1. One or more characters treated as a unit.
2. A specified area of a record used for a single type of data.

file A logical collection of data treated as a unit. It occupies one or more blocks on a mass-storage device such as disk, DECtape, or magtape. A file can be referenced by a logical name.

file gap A fixed length of blank tape separating files on a magnetic tape volume.

file name The alphanumeric character string assigned by a user to identify a file, and which can be read by both an operating system and a user. A file name identifies a unique member of a group of files which: 1) has the same file name extension and version number (if any), 2) is located on the same volume, and 3) belongs in the same User File Directory (if any). A file name has a fixed maximum length which is system dependent (generally six or nine characters).

file specification A name that uniquely identifies a file maintained in any operating system. A file specification generally consists of at least three components: a device name identifying the volume on which the file is stored, a file name, and a file type. In addition, depending on the system, a file specification can include a User File Directory name or UIC, and a version number.

file structure A method of recording and cataloging files on mass-storage media.

file-structured device A device on which data are organized into files. The device usually contains a directory of the files stored on the device.

file type The alphanumeric character string assigned to a file either by an operating system or a user, and which can be read by both the operating system and the user. System-recognizable file types are used to identify files having the same format or type (e.g., FORTRAN source files might have the file type .FOR in its file specification). A file type follows the file name and is separated from it by a period. A file name extension has a fixed maximum length which is system dependent (generally three characters, excluding the preceding period).

flag A variable or register used to record the status of a program or device. In the latter case it is sometimes called a device flag.

floating point numeric A floating point number which, if stored in four words, is approximately in the range 10^{-38} to 10^{38}.

foreground 1. The area in memory designated for use by a high-priority program.

2. The program, set of programs, or functions that gain the use of machine facilities immediately upon request.

format The arrangement of the elements constituting any field, record, file, or volume.

formatted ASCII Refers to a mode in which data are transferred. A file containing formatted ASCII data is generally transferred as strings of 7-bit ASCII characters (bit eight is zero) terminated by a line feed, form feed or vertical tab. Special characters, such as NULL, RUBOUT, and TAB may be interpreted specially.

formatted binary Refers to a mode in which data are transferred. Formatted binary is used to transfer checksummed binary data (8-bit characters) in blocks. Formatting characters are start-of-block indicators, byte count, and checksum values.

formatted device A volume which has been prepared for use on a system under program control.

frame That part of the packet carrying data required by the link control protocol and defining the leading and trailing ends of the bit stream.

full-duplex The line can transmit data in both directions simultaneously. A full-duplex line allows a node to send and receive data at the same time.

fully connected network A network in which each node is directly connected with every other node.

function An algorithm accessible by name and contained in the system software. It performs commonly-used operations, such as the square root calculation function.

generation number See *version number.*

global A value defined in one program module and used in others. Globals are often referred to as entry points in the module in which they are defined, and externals in the other modules which use them. Also, in the DSM-11 system, a global array.

global array A data file stored in the common DSM-11 data base. Global arrays constitute an external system of symbolically referenced arrays.

global variable A global variable in the DSM-11 system is a subscripted variable which forms a part (or node) of a global array.

half-duplex The line can transmit data in either direction, but only in one direction at any given time. In other words, the line cannot be used to send and receive data simultaneously.

handler See *device handler.*

hard copy A printed copy on some kind of paper, generally in readable form, such as listings and other documents.

hardware The physical equipment components of a computer system.

HASP Houston Automatic Spooling Program. An IBM 360/370 OS software front-end which performs job spooling and controls communications between local and

remote processors and Remote Job Entry (RJE) stations.

higher level language A programming language whose statements are translated into more than one machine language instruction. Examples are BASIC, FORTRAN, and COBOL.

host A computer connected to a network and implementing its protocols in such a way that its computing power is accessible through the network.

host node A node that provide services for another node. For example, the host node supplies program image files for a down-line load.

idle time That part of uptime in which no job could run because all jobs are halted or waiting for some external action such as I/O.

image mode Refers to a mode of data transfer in which each byte of data is transferred without any interpretation or data changes.

impure code The code which is modified during the course of a program's execution, e.g., data tables.

incremental compiler A compiler that immediately translates each source statement into an internal format, ready for execution.

indirect file or indirect command file A file containing commands that are processed sequentially, yet which could have been entered interactively at a terminal.

indirect reference A feature of the MUMPS language which permits the symbolic representation of an argument or argument list in a command by a string variable. In operation, the string value of the variable is taken as the argument or argument list for the command. The indirection symbol, a back-arrow (←) or underscore (_), must precede the variable reference.

initialize To set counters, switches, or addresses to starting values at prescribed points in the execution of a program, particularly in preparation for re-execution of a sequence of code. To format a volume in a particular file-structured format in preparation for use by an operating system.

input 1. Data to be processed. 2. The process of transferring data to memory from a mass storage device or from other peripheral devices which read data from other media.

instruction One unit of machine language, usually corresponding to one line of assembly language, which tells the computer what elementary operation to do next.

interactive A technique of user/system communication in which the operating system immediately acknowledges and acts upon requests entered by the user at a terminal. Compare with *batch*.

interface A shared boundary, for example, the wires and perhaps other electronics connecting two subsystems.

Internet A network linking DIGITAL computers to non-DIGITAL computers.

interpreter A computer program that translates and executes each source lan-

guage statement before translating and executing the next statement.

interrupt A signal which, when activated, causes a transfer of control to a specific location in memory, thereby breaking the normal flow of control of the routine being executed. An interrupt is normally caused by an external event such as a done condition in a peripheral. It is distinguished from a trap which is caused by the execution of a processor instruction.

interrupt service routine The routine entered when an external interrupt occurs.

interrupt vector address A unique address which points to two consecutive memory locations containing the start address of the interrupt service routine and priority at which the interrupt is to be serviced.

I/O bound A state of program execution in which all operations are dependent on the activity of an I/O device. For example, when a program is waiting for input from a terminal. Compare *compute bound.*

I/O page That portion of memory in which specific storage locations are associated directly with I/O devices.

I/O rundown A process which delays the availability of a partition until all transfers to and from that partition have been stopped or have been allowed to complete. I/O rundown is invoked when a task is terminated and has outstanding transfers pending to or from its partition.

job A group of data and control statements which does a unit of work, e.g., a program and all its related subroutines, data and control statements; also, a batch control file.

journaling The parallel writing of updated records to a second medium in addition to the original file.

K 1. An abbreviation for the prefix kilo, i.e., 1000 in decimal notation.
2. In the computer field, two to the tenth power, which is 1024 in decimal notation. Hence, a 4K memory has 4096 words.

keyboard monitor A program that provides and supervises communication between the user at the system console and an operating system.

latency 1. The time from initiation of a transfer operation to the beginning of actual transfer; i.e., verification plus search time.
2. The delay while waiting for a rotating memory to reach a given location.

leader A blank section of tape at the beginning of a reel of magnetic tape or at the beginning of paper tape.

leased-line A line reserved for the exclusive use of a leasing customer without interchange switching arrangements. Also called a private line.

library 1. A file containing one or more relocatable binary modules which are routines that can be incorporated into other programs.
2. A class of MUMPS programs listed in the system program directory and available to all users of the system.

line 1. A string of characters terminated with a vertical tab, form feed, or line feed.
2. The network management component that provides a distinct physical data path.

linked file A file whose blocks are joined together by references (a link word or pointer imbedded in the block) rather than consecutive location.

linker A program that combines many relocatable object modules into an executable program module. It satisfies global references and combines control sections.

linking loader A program that provides automatic loading, relocation, and linking of compiler and assembler generated object modules.

listing The hard copy generated by a lineprinter.

literal An element of a programming language which permits the explicit representation of character strings in expressions and command and function elements. In most languages, a literal is enclosed in either single or double quotes to denote that the enclosed string is to be taken "literally" and not evaluated.

load 1. To store a program or data into memory.
2. To mount a tape on a device such that the read point is at the beginning of the tape.
3. To place a removable disk in a disk drive and start the drive.

load image file A program that can be executed in a stand-alone environment without the aid of relocation.

load map A table produced by a linker that provides information about a load module's characteristics, e.g., the transfer address and the low and high limits of the relocatable code.

load module A program in a format ready for loading and executing.

local node A frame of reference; the node at which the user is physically located.

local variable In the DSM-11 system, a local variable is a variable which is stored only in the partition in which a program is executed (as opposed to a global variable).

location An address in storage or memory where a unit of data or an instruction can be stored.

log in To identify oneself to an operating system as a legitimate user of the system and gain access to its services.

log out or log off To sign off a system.

logical block An arbitrarily defined, fixed number of contiguous bytes which is used as the standard I/O transfer unit throughout an operating system. For example, the commonly-used logical block in PDP-11 systems is 512 bytes long. An I/O device is treated as if its block length is 512 bytes, although the device may have an actual (physical) block length which is not 512 bytes. Logical blocks on a device are numbered from block 0 consecutively up to the last block on the volume. A logical block is synonymous with a physical block on any device that has 512-byte physical blocks. See also *virtual block, physical block, logical record, and physical record.*

logical device name An alphanumeric name assigned by the user to represent a physical device. The name can then be used synonymously with the physical device name in all references to the device. Logical device names are used in device-independent systems to enable a program to refer to a logical device name which can be assigned to a physical device at run time.

logical link A carrier of a single stream of full-duplex traffic between two user-level processes.

logical record A logical unit of data within a file whose length is defined by the user and whose contents have significance to the user. A group of related fields treated as a unit.

logical unit number A number associated with a physical device unit during a task's I/O operations. Each task in the system can establish its own correspondence between logical unit numbers and physical device units.

machine language The language, peculiar to each kind of computer, that that computer understands. It is a binary code which contains an operation code to tell the computer what to do, and an address to tell the computer on which data to perform the operation.

macro Directions for expanding abbreviated text. A boilerplate that generates a known set of instructions, data or symbols. A macro is used to eliminate the need to write a set of instructions which are used repeatedly. For example, an assembly language macro instruction enables the programmer to request the assembler to generate a predefined set of machine instructions.

main memory The set of storage locations connected directly to the Central Processing Unit. Also called (generically) core memory.

main program The module of a program that contains the instructions at which program execution begins. Normally, the main program exercises primary control over the operations performed and calls subroutines or subprograms to perform specific functions.

mapped system A system which uses the hardware memory management unit to relocate virtual memory addresses.

mass storage Pertaining to a device which can store large amounts of data readily accessible to the Central Processing Unit; for example, disk, DECtape, magnetic tape, etc.

master file directory The system-maintained file on a volume that contains the names and addresses of all the files stored on the volume.

matrix A rectangular array of elements. A table can be considered a matrix.

memory Any form of data storage, including main memory and mass storage, in which data can be read and written. In the strict sense, memory refers to main memory.

memory image A replication of the contents of a portion of memory.

memory mapping A mode of computer operation in which the high-order bits

of a virtual address are replaced by an alternate value, providing dynamic relocatability of programs.

memory protection A scheme for preventing read and/or write access to certain areas of memory.

modulo A mathematical operation that yields the remainder function of division. Thus 39 modulo 6 equals 3.

monitor The master control program that observes, supervises, controls, or verifies the operation of a computer system. The collection of routines that controls the operation of user and system programs, schedules operations, allocates resources, performs I/O, etc.

monitor command An instruction issued directly to a monitor from a user.

monitor console The system control terminal.

Monitor Console Routine (MCR) The executive routine that allows the user to communicate with the system using an on-line terminal device. MCR accepts and interprets commands typed on the terminal keyboard and calls appropriate routines to execute the specified requests.

mount a device or volume To associate a physical mass storage media logically with a physical device unit. To place a volume on a physical mass storage drive unit; for example, place a DECtape on a DECtape drive and put the drive on-line.

multiplexing Use of one communications line circuit for two or more simultaneous data paths.

multipoint A communication line (circuit) with three or more communicating devices on it (terminals or computers). Use of this type of line normally requires a polling technique with an address for each device. Also called multidrop.

multiprocessing Simultaneous execution of two or more programs by two or more processors.

multiprogramming A processing method in which more than one task is in an executable state at any one time.

naked syntax A feature of the MUMPS language, providing an abbreviated method for accessing global variables, which controls the disk access time. The node reference includes only subscript(s) for the element; the global variable name is assumed from the last global reference in which a name was explicitly stated.

network A configuration of two or more computers linked to share information and resources. A computer having the capacity to participate in a network is called a node.

node 1. A dynamically allocated set of bytes from a node pool used for system communication and control in an RSX-11/IAS system.
2. An element of a global array in a DSM-11 system (also called a global variable).
3. A network management component consisting of a system that supports network software.

noncontiguous file A file whose blocks are not physically contiguous on the volume.

non-file-structured device A device, such as paper tape, lineprinter or terminal, in which data are not referenced as a file.

nonrouting (end) node A nonrouting node can send packets to other nodes in the network, but it cannot forward packets or route them through itself. It can be adjacent to one other node only; therefore, it is always an end node in a Phase III configuration.

null modem A device which interfaces between a local peripheral that normally requires a modem, and the computer near it that expects to drive a modem to interface to that device; an imitation modem in both directions.

object code Relocatable machine language code.

object module The primary output of an assembler or compiler; it can be linked with other object modules and loaded into memory as a runnable program. The object module is composed of the relocatable machine language code, relocation information, and the corresponding symbol table defining the use of symbols within the module.

object program The relocatable binary program which is the output of a compiler or assembler.

Object Time System The collection of modules that is called by compiled code in order to perform various utility or supervisory operations. For example, an Object Time System usually includes I/O and trap handling routines.

octal Pertaining to the base eight number system.

off-line Pertaining to equipment or devices not under direct control of the Central Processing Unit.

offset The difference between a base location and the location of an element related to the base location. The number of locations relative to the base of an array, string or block.

on-line Pertaining to equipment or devices directly connected and under control of the Central Processing Unit.

operating system The collection of programs, including a monitor or executive and system programs, that organizes a central processor and peripheral devices into a working unit for the development and execution of application programs.

output 1. The results of processing data. 2. The process of transferring data from memory to a mass storage device or from memory to a copying device such as a lineprinter or paper tape punch. 3. The process of moving information from a mass storage device to a copying device. 4. The peripheral device receiving the information described above.

overlay description language The set of instructions interpreted by a linker that defines the overlay structure of a task.

overlay segment A section of code treated as a unit which can overlay code already in memory and be overlaid by other overlay segments.

overlay structure A task overlay system consisting of a root segment and optionally one or more overlay segments.

p-section (program section) A section of memory that is a unit of the total task allocation. A source program is translated into object modules that consist of p-sections with attributes describing access, allocation, relocatability, etc.

pack 1. To compress data in storage by using an algorithm for its storage and retrieval. 2. A removable disk.

packet The unit of data switched through a Packet Switching Service, normally a user data field accompanied by a header carrying destination and other information and enclosed in a frame, possibly shared with other packets.

packet switching A data transmission process utilizing addressed packets, whereby a channel is occupied only for the duration of transmission of the packet.

parity bit A binary digit appended to a group of bits to make the sum of all the bits always odd (odd parity) or always even (even parity). Used to verify data storage.

parse To break a command string into its elemental components for the purpose of interpretation.

part number In the MUMPS language, the integer portion of a program step which is used to refer collectively to all steps having a common integer base.

partition A contiguous area of memory within which tasks are loaded and executed.

patch To modify a program by changing the binary code rather than the source code.

peripheral Any device distinct from the central processor which can provide input to or accept output from the computer.

Phase II node A node which runs a Phase II implementation of DECnet and, therefore, does not support routing. It can send packets only to adjacent nodes and it cannot forward packets it receives on to other nodes in the network. It can be adjacent to one or more full-routing nodes and/or to other Phase II nodes. Logically, it is an end node within a Phase III configuration.

Phase III node A node which runs under a Phase III implementation of DECnet and supports routing as either a full-routing or nonrouting (end) node. See also *routing node.*

physical address space The set of memory locations where information can actually be stored for program execution. Virtual memory addresses can be mapped, relocated, or translated to produce a final memory address which is sent to hardware memory units. The final memory address is the physical address.

physical block A physical record on a mass storage device.

physical device An I/O or peripheral storage device connected to or associated with a central processor.

physical record The largest unit of data that the read/write hardware of an I/O device can transmit or receive in a single I/O operation. The length of a physical record is device dependent. For example, a punched card can be considered the physical record for a card reader; it is 80 bytes long. The physical record for an RK11 disk is a block; it is 512 bytes long.

position independent code Code which can execute properly wherever it is loaded in memory, without modification or relinking. Generally, this code uses addressing modes which form an effective memory address relative to the central processor's Program Counter (PC).

priority A number associated with a task that determines the preference its requests for service receive from the executive, relative to other tasks requesting service.

privilege A characteristic of a user or program that determines what kinds of operations that user or program can perform. In general, a privileged user or program is allowed to perform operations normally considered to be the domain of the monitor or executive or which can affect system operation as a whole.

program development The process of writing, entering, translating, and debugging source programs.

programmed requests An instruction (available only to programs) that is used to invoke a monitor service.

programmer access code The system identification code that enables a user to gain access to a DSM-11 system in direct mode to create, modify, and execute programs.

project-programmer number See *account number.*

protocol A formal set of conventions governing the format and relative timing of message exchange between two communicating processes.

pseudo device A logical entity treated as an I/O device by the user or the system, but which is not actually any particular physical device.

PTT Abbreviation for the post, telegraph and telephone adminstrations which act as common carriers for telecommunications in many European and other countries.

public disk structure The disk volume or set of volumes which are used as a general storage pool available to any users having quotas on the public structure.

pure code Code that is never modified during execution. It is possible to let many users share the same copy of a program that is written as pure code.

qualifier A parameter specified in a command string that modifies some other parameter. See *switch*.

queue Any list of items; for example, items waiting to be scheduled or waiting to be processed according to system- or user-assigned priorities.

Radix-50 A storage format in which three ASCII characters are packed into a 16-bit word.

random access Access method in which the next location from which data is to be obtained is not dependent on the location of the previously obtained data.

read To transfer information from a peripheral device into core memory or into a register in the CPU.

real time processing Computation performed while a related or controlled physical activity is occurring, so that the results of the computation can be used in guiding the process.

record A collection of adjacent data items treated as a unit. See *logical record* and *physical record.*

record gap An area between two consecutive records.

recursive Pertaining to a process that is inherently repetitive. The result of each iteration of the process is usually dependent on the result of the previous iteration.

re-entrant The property of a program that enables it to be interrupted at any point by another program, and then resumed from the point where it was interrupted.

relocatable Describes a routine, module, or segment whose address constants can be modified to compensate for a change in origin.

remote batch terminal A combination of hardware items (usually a card reader, communication interface and a printer) and a communication link that allows the transmission of a series of records (the job) to a host computer. The host processes the records as a job stream and transmits the results of the job back to the lineprinter. Communiation is typically at the file level. See also *RJE emulator, RJE.*

remote node A frame of reference; any node other than the one at which the user is located in the network. Compare *local node.*

resident Pertaining to data or instructions that are normally permanently located in main memory.

resource sharing The joint use of resources available on a network by a number of dispersed users.

restart address The address at which a program can be restarted. It is normally the address of the code required to initialize variables, counters, etc.

root segment The segment of an overlay tree that, once loaded, remains resident in memory during the execution of a task.

routine A set of instructions arranged in proper sequence to cause the computer to perform a desired task.

routing node A full-routing node can forward packets to other nodes in the network and can be adjacent to all other types of nodes.

secondary storage Mass storage other than main memory.

segment 1. That part of a long program which may to resident in core at any one

time. 2. To divide a program into segments or to store part of a program on a mass storage device to be brought into memory as needed.

sentinel file The last file on a cassette tape which represents the logical end-of-tape.

sequential access A data access method in which records or files are read one after another in the order in which they appear in the file or volume.

shareable program A (re-entrant) program that can be used by several users at the same time.

significant event An event or condition which indicates a change in system status in an event-driven system. A significant event is declared, for example, when an I/O operation completes. A declaration of a significant event indicates that the executive should review the eligibility of task execution, since the event might unblock the execution of a higher priority task. The following are considered to be significant events: I/O queuing, I/O request completion, a task request, a scheduled task execution, a mark time expiration, a task exit.

single user access The status of a volume that allows only one user to access the file structure of a volume.

single-stream batch A method of batch processing in which only one stream of batch commands is processed.

sliver A 32-word section of memory.

source language The system of symbols and syntax, easily understood by people, which is used to describe a procedure that a computer can execute.

sparse array Refers to the method of storage allocation used in MUMPS for local and global arrays in which space is allocated only as variables are explicitly defined (unlike some other languages which require dimension or size statements for preallocation of storage).

spooling The technique by which output to low-speed devices (e.g., lineprinters) is placed into queues on faster devices (e.g., disks) to await transmission to the slower devices.

statement An expression or instruction in a source language.

step number A number in the range 0.01 to 327.67 used to identify each line of a MUMPS program.

string A connected sequence of entities such as a line of characters.

subscript A numeric valued expression which is appended to a variable name to identify specific elements of an array. Subscripts are enclosed in parentheses. Multiple subscripts must be separated by commas. For example, a two-level subscript might be (2,5).

swapping The process of copying areas of memory to mass storage and back in order to use the memory for more than one purpose. Data are swapped out when a copy of the data in memory is placed on a mass storage device; data are swapped in when a copy on a mass storage device is loaded in memory

swapping device A mass storage device especially suited for swapping because of its fast transfer rate.

switch An element of a command or command string that enables the user to choose among several options associated with the command. In PDP-11 software systems, a switch element consists of a slash character (/) followed by the switch name and, optionally, a colon and a parameter. For example, a command used to print three copies of a file on the lineprinter could be: "PRINT filename/COPIES:3."

synchronous The performance of a sequence of operations controlled by an external clocking device. Implies that no operation can take place until the previous operation is complete.

synchronous system trap A system condition which occurs as a result of an error or fault within the executing task.

system device The device on which the operating system is stored.

system generation The process of building an operating system on or for a particular hardware configuration with software configuration modifications.

system manager The person at a computer installation responsible for the overall nature of its operation.

system operator See *operator.*

system program 1. A program that performs system-level functions. 2. Any program that is part of the basic operating system. 3. A system utility program.

system programmer A person who designs and codes the programs that control the basic operations of a computer system, as opposed to an application programmer.

system UCI The User Class Identifier (UCI) code in a DSM-11 system which is assigned to the first entry in the system's UCI table. The program and global directories associated with the System UCI are used to contain both system and library programs and globals.

task In RSX-11 terminology, a load module with special characteristics. In general, any discrete operation performed by a program.

TELENET The Packet-Switching Network available in the U.S.A.

terminal An I/O device, such as an LA36 terminal, which includes a keyboard and a display mechanism. In PDP-11 systems, a terminal is used as the primary communication device between a computer system and a person.

time quantum In time-sharing, a unit of time alloted each user by the monitor.

timesharing A method of allocating CPU time and other computer services to multiple users so that the computer, in effect, processes a number of programs concurrently.

time slice The period of time allocated by the operating system to process a particular program.

topology The physical or logical placement of nodes in a computer network.

transaction A single predefined data processing operation within an application.

transaction processor A collection of data tables and software capable of processing an application's transactions.

tributary station A station, other than the control station, on a centralized multipoint data communication system, which can communicate only with the control station when polled or selected by the control station.

turnkey 1. Pertaining to a computer system and its software which are sold together ready to go. 2. A computer console containing only one control, a power switch to turn the system on and off.

staging The delay of each update to a file until the end of the transaction instance requesting the update.

unattended operation The automatic features of a node's operation which permit the transmission and reception of messages on a unattended basis.

unbundling A practice by which a computer manufacturer does not sell computer equipment and software under one price structure, but sells them separately.

unformatted ASCII A mode of data transfer in which the low-order seven bits of each byte are transferred. No special formatting of the data occurs or is recognized.

unformatted binary A mode of data transfer in which all bits of a byte are transferred without regard to their contents.

UNIBUS The single, asynchronous, high-speed bus structure shared by the PDP-11 processor, its memory, and all of its peripherals.

unmapped system An RSX-11M or RSX-11S system that does not have a hardware memory management unit available for virtual address relocation.

user class identifier An identification code that enables a user to gain access to a DSM-11 system to execute programs.

user identification code The number or set of numbers that serves to distinguish a particular user or collection of files in a multiuser system. The common format for a user identification code is two numbers separated by a comma, enclosed in brackets, e.g., [3,11].

user program An application program.

utility Any general-purpose program included in an operating system to perform common functions.

variable The symbolic representation of a logical storage location which can contain a value that changes during a discrete processing operation.

virtual address space A set of memory addresses that is mapped into physical memory addresses by the paging or relocation hardware when a program is executed.

virtual array A RSTS/E file structure that is logically organized as a dimensioned array.

virtual block One of a collection of blocks constituting a file (or the memory

image of that file). The block is virtual only in that its block number refers to its position relative to other blocks within the file, instead of to its position relative to other blocks on the volume. That is, the virtual blocks of a file are numbered sequentially beginning with one, while their corresponding logical block numbers can be any random list of valid volume-relative block numbers.

volume A mass storage media that can be treated as file-structured data storage.

word Sixteen binary digits treated as a unit in PDP-11 processor memory.

X.25 A communication protocol created by CCITT that recommends how a computer connects to a packet switched network. PTTs have accepted X.25 as their standard for Public Packet Switching Networks.

zero a device To erase all the data stored on a volume and re-initialize the format of the volume.

INDEX

A

B

C

E

G

H

I

J

K

Q

R

T

U

V

W

X

Z

1984-85 PDP-11 SOFTWARE HANDBOOK
READER's COMMENTS

Your comments and suggestions will help us in our continuous effort to improve the quality and usefulness of our handbooks.

What is your general reaction to this handbook? (format, accuracy, completeness, organization, etc.)____

What features are most useful?____

Does the publication satisfy your needs?________________________________

What errors have you found?____

Additional Comments____

Name

Title

Company Dept.

Address

City State Zip

(staple here)

(staple here)

(please fold here)

No Postage
Necessary
if Mailed in the
United States

BUSINESS REPLY MAIL

FIRST CLASS PERMIT NO. 33 MAYNARD, MASS.

POSTAGE WILL BE PAID BY ADDRESSEE

Digital Equipment Corporation
Corporate Marketing Services
200 Baker Avenue (CFO1-2/M92)
West Concord, MA 01742

ORDER CODE: EB-25398-41

digital